HYPERCONNECTED

SMART CITY DEMONSTRATORS

A global review of challenges and lessons learned

Catapult Future Cities

FOREWORD

Nicola Yates OBE – Chief Executive Officer, Future Cities Catapult

Future Cities Catapult works with cities in the UK and around the world to help deliver innovation at city scale. We know that to achieve such results cities must share knowledge, build partnerships and ultimately create an ecosystem where government, businesses and citizens can creatively collaborate.

A common approach to accelerating the development, testing and wider market creation for smart city solutions and services is through the creation of city-based demonstrators.

The aim of these demonstrators is to de-risk the development and scaling-up of solutions and services that are not yet ready for the mainstream market by providing safe environments for experimentation and innovation.

For this reason, Future Cities Catapult has undertaken an extensive research exercise to understand what can be learned from previous demonstrators, to inform the next generation of city-based projects.

Ian Meikle – Director Clean Growth and Infrastructure at Innovate UK

Our cities are facing increasingly complex challenges such as air pollution, population growth and road congestion. How can cities find innovative approaches to addressing these complex challenges?

Smart City Demonstrators are an approach to demonstrating the value of data at city-scale. The digital technologies deployed help address environmental, economic and financial challenges. A successful outcome is market creation and investment for businesses and SMEs and the creation of an exciting and healthy environment for citizens to live, work and play.

Providing insights into how these demonstrators have tackled barriers and found new innovative approaches and opportunities will help not only these cities but others that follow in their digital footsteps to deliver successful outcomes in the years to come.

CATAPULT Future Cities

Future Cities Catapult accelerates urban ideas to market, to grow the British economy and make cities better. It brings together businesses, universities and city leaders so that they can work with each other to solve the problems that cities face, now and in the future.
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Innovate UK

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EXECUTIVE SUMMARY

The transition to smarter cities is driven by a number of factors across the globe, including:

- **Increasing urbanisation**
- **Growing stress on resources**
- **Inadequate infrastructure**
- **Rising environmental challenges**
- **Rapidly improving technology capabilities [1]**

Despite the presence of these drivers, many smart city solutions remain in the pre-commercial phase of development.

A common approach to accelerating the development, testing and wider market creation for smart city solutions and services is through the creation of demonstrators. These initiatives aim to de-risk the development and scaling-up of solutions and services that are not yet ready for the mainstream market by providing safe environments for experimentation and innovation.

While numerous test beds have been created and countless demonstration projects have been carried out around the world, relatively few have led to the scaling and operationalisation of smart city solutions. Despite this, huge sums of money continue to be invested in these initiatives.

For this reason, the Future Cities Catapult has undertaken an extensive research exercise to understand what can be learned from previous demonstrators.

We have undertaken a comprehensive desk-based research study to identify prominent large-scale smart city demonstrators both within the UK and internationally. These demonstrators fall into the following market verticals: city services, smart utilities, smart healthcare, connected and autonomous vehicles, last mile supply chain and logistics, and next-generation connectivity and data.

Using this research as a base, we selected a subset of demonstrators and conducted 40 in-depth interviews with representatives and industry experts to uncover challenges, lessons learned and best practice.

In summary, this report aims to:

- **Provide a view of the global smart city demonstrator landscape**
- **Identify trends with regards to aims, scale, funding sources, use-cases and locations of demonstrators**
- **Analyse common challenges experienced by demonstrators across a range of market verticals**
- **Discover and share what lessons have been learned during the planning, delivery and management phases of previous demonstrators**
- **Highlight innovative ways in which demonstrators have overcome the challenges they have experienced**

It is hoped that this piece of research will help future demonstrators avoid the mistakes made by those before them and support them in delivering successful outcomes.

GLOBAL DEMONSTRATOR LANDSCAPE

Our research has identified over 150 large-scale smart city demonstrators globally. Demonstrators were selected using criteria such as size, location and status.

City services demonstrators: The past five years have seen an explosion in the number of smart city demonstrators aiming to deliver solutions that will increase the efficiency and effectiveness of everyday city services. This has led to the creation of some of the largest and most costly demonstrators included in this report. Most notably, Middle Eastern countries, such as the United Arab Emirates, Qatar and Saudi Arabia, have invested billions of dollars in the creation of smart city demonstrators.

The UK has emerged as a strong force in the city services demonstrator space, with several prominent project examples, including the Future City Glasgow, Manchester CityVerve and MK:Smart demonstrators. The UK also participates in a large number of European Commission-funded programmes. Nordic cities such as Copenhagen and Helsinki have had the most success in transforming areas of their cities into multi-use test beds for innovation. This trend for multi-use demonstrators was not replicated elsewhere, with many demonstration projects setting up their own single-use test beds for the duration of their projects.

The use-cases tested in city services demonstrators around the world remained relatively constant, with smart traffic management, smart parking, smart street lighting and smart waste management being most common.

Smart utility demonstrators: The water and energy sectors are currently facing challenges in meeting increased demand and environmental targets. The most common applications piloted in demonstrators were found to be smart meters, smart grids and dynamic energy marketplaces. There was also a growing trend to deliver energy as a service to consumers, rather than as a commodity.

Within the UK, our research revealed a wide variety of demonstrators, ranging from discrete projects that aim to pilot smart micro-grid solutions and dynamic energy marketplaces, to those that create test bed facilities in the public or private domain to allow the testing of numerous smart utility applications. Several water companies have designated parts of their live networks as test beds to enable the demonstration of future water-monitoring solutions.

The international smart utility demonstrator landscape is characterised by very large electrical smart grid projects which aim to facilitate the incorporation of renewable energy sources and to cope with the stress that electric vehicle charging places on the existing energy infrastructure.

Smart healthcare demonstrators: Ageing populations are leading to an increase in age-related health conditions and demand for adequate social care, creating challenges for healthcare providers. In order to handle this increase in demand for health services, there is a growing focus on using demonstrators to:

- **Design buildings and communities that are appropriate for all ages**
- **Enable the self-monitoring of chronic conditions**

EXECUTIVE SUMMARY

- **Deploy assisted living technologies to support people staying in their homes longer**

Benefitting from a centralised and publicly operated healthcare system, the UK is a leader in the smart healthcare demonstrator space having launched several large-scale projects in the last 10 years. These include the Delivering Assisted Living Lifestyles at Scale (DALLAS) programme and the Whole System Demonstrator, which is believed to be the largest randomised controlled trial of telecare and telehealth in the world to date.

In Europe, the European Commission has funded several large smart health demonstrators, and Asian countries, including Singapore, Japan and Thailand, have also launched large-scale initiatives in recent years.

More broadly, the wider health demonstrator landscape is typified by a number of incubators, accelerators and technology clusters which support the creation of solutions by businesses, who then run smaller-scale pilots with local health providers.

Connected and autonomous vehicle (CAV) demonstrators: In recent years, there has been a rapid worldwide proliferation in the number of CAV demonstrators.

Our analysis has shown that the focus of CAV demonstrators spans the SAE autonomy-level spectrum, ranging from those aiming to deliver driver assistance (level 1) use-cases to those focused on high automation (level 4) demonstrations in real-world conditions. Demonstration projects also seek to address legal, societal and regulatory challenges that may inhibit large-scale CAV deployment.

Within the UK, a number of geographical areas are emerging as front runners in the real-world testing and deployment of CAVs, including London, Milton Keynes, Coventry, Bristol and Oxford. The CAV agenda has received strong support from government through the creation of the Centre for Autonomous and Connected Vehicles (CCAV), which has provided over £250m in funding for demonstration projects and test beds since 2015.

Internationally, a large number of countries are pushing ahead with the CAV agenda, including Singapore, Germany, USA, China, Korea and Sweden. The landscape is punctuated with a large number of private-land proving grounds, accompanied by a smaller number of on-road trials.

Last mile supply chain and logistics demonstrators: The number of freight vehicles entering urban areas is causing economic, social and environmental impacts in the form of congestion and noise and air pollution. In response to these impacts, investments are being seen in a range of demonstrators aiming to pilot the following technologies and solutions:

- **'Green' delivery vehicles**
- **Advanced algorithms and analytics**
- **Delivery drones and robots**

Globally, the majority of demonstrators in this space are focused on introducing electric freight vehicles and other environmentally friendly goods delivery options.

Emerging technology solutions such as drones and delivery robots are starting to be demonstrated in the public domain. These smaller-scale demonstrators are predominantly driven by the private sector, with little funding coming from public sources.

Next-generation connectivity and data demonstrators: Emerging smart city solutions such as smart city service applications, smart grids and smart healthcare services often rely on the use of connectivity networks. In many cases, the requirements of these smart solutions cannot be met with today's connectivity networks, and therefore demonstrators are being created to enable experimentation with next-generation technologies.

In the UK, demonstrators such as Bristol is Open and the Things Connected programme aim to provide open, experimental, next-generation ICT platforms that can be used by companies and developers to build and test a wide range of applications.

As the definition of 5G continues, several open-access test beds have been created that aim to provide businesses and entrepreneurs with access to emerging 5G technologies. Within the UK, these test beds remain small in scale and are not located in the public realm.

Internationally, 5G trials are continuing at pace in Japan, Germany, China, South Korea, USA, France and Sweden. These small-scale trials are invariably led by respective large telecommunication providers. In addition to trials, a number of open-access, public realm 5G test beds have been established, such as those in Sweden (Urban ICT Arena) and Germany (5G Berlin).

OBSERVATIONS ON THE GLOBAL DEMONSTRATOR LANDSCAPE

Based on our analysis of the global smart city demonstrator landscape, the following observations have been made:

OBSERVATION	DESCRIPTION
Focus of demonstration projects	There appears to be a lot of focus and funding designated to the creation of trials and pilots that aim to demonstrate technical functionality in real-world environments. While these projects are undoubtedly necessary, there is comparatively little focus on creating projects and test beds aimed at enabling the demonstration of commercial viability at scale and the required business models that will lead to transactions in the market.
Technology-led demonstrators	Despite the continuous rhetoric around the smart city agenda seeking to solve city challenges, many demonstrators have ended up as technology demonstrations. A need has been identified for societal challenge-based demonstrators that place city issues front and centre – for example, a congestion-focused demonstrator could involve the demonstration of multiple solutions across market verticals
Funding of demonstrators	The majority of demonstration projects are funded using a grant-based model and create single-use, time-limited testing infrastructures. Test bed environments are often funded by grants and few have plans for self-sustainability. This grant-based funding model causes projects to end abruptly due to short time frames , limits continuity between project phases and does not expect the demonstrator to generate any income to recover the initial investment. This leads to demonstrators being thought of as research infrastructures or marketing tools, rather than strategic projects.

CHALLENGES AND LESSONS LEARNED FROM PREVIOUS DEMONSTRATORS

Challenges and lessons learned fell into four main categories:

Engagement and access to assets

Local authority capacity and engagement: Many large-scale demonstrators cannot happen without the cooperation and participation of local authorities due to the powers they hold and the assets they own. A small number of authorities are actively putting themselves forward as demonstration 'sandpits' in order to attract inward investment. While it is often inferred that authorities do not have the capacity or skills to effectively participate in large-scale innovation programmes, our research has shown that authorities often make valuable contributions to these initiatives, drawing on their strong stakeholder and project management skills.

Access to assets: The successful implementation of many smart city demonstrators depends, in part, on access to physical infrastructure and data assets. The ownership of assets at a city level is not straightforward, with private property rights, privatisation of critical infrastructure and outsourcing of city services inhibiting the execution of integrated programmes. Demonstrators recommended selecting demonstrator locations based on the appetite for innovation of various asset owners, involving owners at the outset of demonstrator planning and using standardised agreements when seeking to deploy equipment onto physical assets.

User research and engagement: A major barrier to the success of smart city demonstrators is the lack of engagement, understanding and trust of people who are expected to be the end users of demonstrated solutions. Our research uncovered a growing trend amongst demonstrators to prioritise user research and engagement, utilising approaches such as co-design workshops, innovation clubs and crowdfunding platforms to select and shape the projects undertaken. For test bed environments, the expected users were often not citizens but businesses. Our research discovered that test beds have experienced difficulties in enabling small businesses to engage with emerging technologies that have long maturity horizons. Several methods were used to attract small business users, including the use of competitions, the use of large businesses to provide use-cases and confidence in the technology, and the use of the Catapult network to direct businesses towards the relevant test beds and provide support.

Finance, Governance and Intellectual Property (IP)

The finance, governance and intellectual property arrangements surrounding smart city demonstrators are intrinsically linked and vary considerably depending on the funding sources, partners involved and use-case area.

Funding and Finance: Funding for demonstrators was received from a number of public and private sources. Common public sources in the UK included central government departments and agencies such as the Department for Digital, Culture, Media and Sport (DCMS), the Department for Transport, the Department for Health, and Innovate UK. Local enterprise partnerships, research councils and various higher education institutional funds also contributed. In Europe, the European Commission was the predominant funder of smart city demonstrators through their Horizon 2020 and European Regional Development Fund (ERDF) avenues. International demonstrators also received considerable support from central and city governments. Universally, public-sector support was typically augmented by private-sector funding in the form of in-kind or material contributions. Rarely was the private sector seen to initiate large-scale smart city demonstrators; when used, this model was almost exclusively seen in North America. Tellingly, very few test bed environments were self-sustaining, with the vast majority relying on continued grant funding to maintain operations.

Governance and Delivery Models: Large demonstration projects, particularly those funded by the European Commission and the UK government, typically utilised collaboration agreements to create delivery consortia comprising public, private and academic organisations. Test bed environments were seen to use special purpose vehicles (SPVs) to enable the participating organisations to achieve their joint objectives. Public-sector organisations stated that the use of SPVs allowed for swifter decision-making capabilities and shorter procurement timescales, while private-sector organisations believed that the use of SPVs offered a degree of protection from potential reputation risks. The various participants in smart city projects and test beds reported challenges in learning to work under these new, multi-agency partnership models, citing cultural differences, resistance to change and little shared history of working together as key contributing factors.

IP Development and Management: Within collaborative demonstration projects, background IP arrangements were found to be standardised, with the party that brought the IP into the consortium retaining full ownership. Foreground IP arrangements became more complex and difficult to agree on as the number of partners increased. Collaboration agreements were found to be the most common way of formalising these arrangements between multiple partners. Projects unanimously reported that these agreements took considerably longer than expected to put in place, with legal negotiations typically lasting between six months and one year. The most common sticking points were intellectual property rights and liabilities.

Delivery Capabilities and Skills

Our research briefly touched upon the skills and capabilities required to deliver large-scale demonstrators. Many of the findings were expected, with project management skills, stakeholder management capabilities, relevant technical skills and legal and financial support all considered critical. Change management was cited as a capability that many demonstrators had not initially prioritised but became crucial as the projects progressed. This support was required to effectively land changes and ensure that they were sustained across all members of the affected ecosystem. Interviewees stressed the importance of partner selection, allowing time for delivery partners to create effective ways of working, and ensuring staff continuity between project phases as key factors in the overall success of demonstrators.

Impact Measurement and Scaling

Measuring impact and success: Measuring the impact of demonstration projects and test beds is critical to proving value, evidencing business cases and ultimately creating new markets. Our analysis found that in the majority of demonstrators, impact measurement activities were conducted by universities, as they had experience of measuring the impact of new and innovative ideas. Difficulties were experienced in measuring long-term impacts and dealing with the frequently changing nature of innovation projects. Baselines set at the beginning of projects were often not suitable for impact measurement purposes by the end. To combat this, demonstrators recommended using a logic model approach to tie activities to outcomes. There were also concerns around too much focus on evaluation and assessment stifling innovation and putting a premature stop to demonstrators.

Scaling to new markets: It is critical for companies to be able to develop and test products and services that can scale to a larger market. Several approaches have been used to scale solutions proven in demonstrators, including expansion of the demonstrator area, operational rollout of the product or services and replication to other locations. A number of methods have been used to facilitate scaling, including:

- **Knowledge-transfer mechanisms such as partnerships, follower-city arrangements and the creation of overarching umbrella programmes**
- **Creation of standards and best-practice frameworks**
- **Engagement of regulatory, legal and policy bodies to ensure solutions are developed in line with actual or anticipated market forces**

Recommendations

Interviews conducted with demonstrator representatives and industry experts have unveiled the challenges, lessons learned and best practices that have emerged during the planning, delivery and operation of demonstration projects and test bed environments. The findings have led us to compile the following list of recommendations for future demonstrators:

LEARNING AREA	RECOMMENDATION
Engagement and Access	Involve relevant asset owners as early as possible during the planning phase to secure buy-in, gain access to assets and enable the smooth deployment of demonstration equipment.
	Invest in user research and user recruitment to ensure that solutions address the needs of citizens and to provide innovators with an engaged cohort of users on which they can test their solutions.
Finance and Governance	Consider ongoing funding and financing options at the outset and build towards a sustainable operation rather than relying on additional grant funding.
	Create advisory boards comprising relevant stakeholders from the wider ecosystem (such as regulators, policy officials, etc.), to ensure that demonstrators are exposed to current and anticipated market conditions.
Delivery Capabilities and Skills	Invest in benefits realisation and change management capabilities to ensure that all stakeholder aims and expectations are aligned, and that the required changes across the affected ecosystem are implemented, accepted and sustained.
	Staff test bed environments with the relevant practitioners to enable non-expert users to make use of the facilities. These environments are rarely able to operate under a ‘plug and play’ model.
Success Measurement and Scaling	Put in place appropriate knowledge-transfer mechanisms to facilitate the scaling of solutions within a city and the replication of demonstrated solutions across locations.
	Work with partners that can provide a pipeline of commercial opportunities beyond the demonstrator period.

CONTENTS

1 INTRODUCTION

1.1 THE SMART CITY AGENDA

The term 'smart city' is poorly defined; however, the majority of definitions involve the application of new technologies, data and citizen-centric approaches to improve the provision and operation of urban infrastructure along with the delivery of city services, with an ultimate aim of solving a city's economic, social and environmental challenges. [2]

MarketsandMarkets estimates that the size of the global smart city market was USD 424.68 billion in 2017, and is expected to rise to USD 757.74 billion by 2020. [3]

The transition to smarter cities is driven by a number of factors around the globe, including:

- **Increasing urbanisation:** people are moving to cities at an alarming rate, attracted by greater employment opportunities and increased access to healthcare and education services.

In 2014, 54% of the total world population lived in urban areas, and this is set to rise to 66% by 2050. In the UK, over 80% of the population is expected to be urbanised by 2030. [4]

- **Growing stress on resources:** city resources and services are being stressed by increasing populations, rising costs, decreasing municipal budgets and stricter environmental requirements.

- **Inadequate infrastructure:** growing populations are putting pressure on city infrastructure which has often been built to accommodate much smaller populations.

- **Rising environmental challenges:** Cities consume as much as 80% of energy production worldwide and account for a roughly equal share of global greenhouse gas emissions. With this in mind, cities will need to lead efforts to reduce resource consumption and emissions if the effects of climate change are to be mitigated. [5]

- **Rapidly improving technology capabilities:** new advances in technology and data, combined with the reduced costs of connectivity, are enabling cities to manage infrastructure, provide services and improve liveability more efficiently and effectively. [1]

Despite the presence of numerous drivers, many smart city solutions are still in their pre-commercial stage of development, and the risk-sharing mechanisms and business models needed to take them forward are yet to be tested and developed. [2] This has led to the creation of numerous smart city demonstrators around the world.

"A common approach to accelerating the development, testing and wider market creation for smart city solutions and services is through the creation of city-based demonstrators."

Nicola Yates OBE
Chief Executive Officer, Future Cities Catapult

1.2 THE ROLE OF DEMONSTRATORS

A common approach to accelerating the development, testing and wider market creation for smart city solutions and services is through the creation of demonstrators.

In a broad sense, demonstrators aim to de-risk the development and scale-up of innovative products, services and solutions that are not yet ready for the mainstream market. They do this by providing safe environments in which solutions can be developed, tested and proven.

These safe environments manifest themselves not only in terms of the physical or virtual spaces in which demonstrations are carried out, but also in the collaborative relationships between involved stakeholders. Success it not guaranteed, experimentation is encouraged, and failure and iteration are accepted as fundamental elements of the innovation process.

At a lower level, demonstrators have many different objectives, ranging from enabling new product development to testing technical functionality, developing new business models, proving commercial viability and acting as a showcase for new solutions and services.

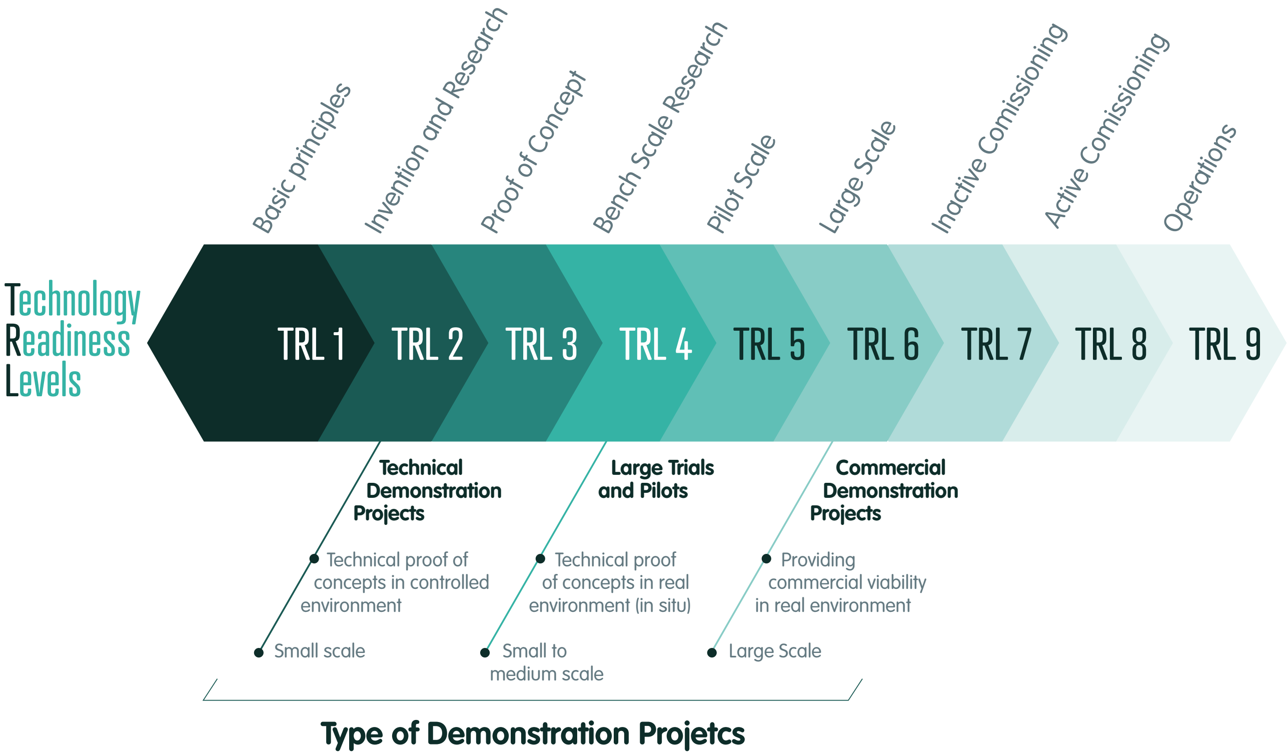
For the purpose of this report, we have felt it necessary to distinguish between individual projects, or groups of projects, that aim to demonstrate discrete products, solutions or services and the underlying enabling infrastructures, or test bed environments, in which multiple demonstration projects take place. At times, the two areas will be referred to collectively as demonstrators.

Demonstration Projects: The diagram below details the various permutations of demonstration projects uncovered during our research. Trends were identified relating to technology readiness level (TRL), scale of demonstrator (both in terms of funding amounts and geographical coverage) and purpose.

Enabling Infrastructure and Platforms: In addition to discrete demonstration projects, our research revealed the presence of a number of underlying experimentation infrastructures or platforms which enabled the execution of multiple demonstration projects.

Common types of underlying infrastructure or platforms include:

- **Test beds:** a physical or virtual infrastructure that enables experimentation, development or testing of products, providing a solutions services platform for experimentation of projects.[6] For example, the Power Networks Demonstration Centre.



- **Living labs:** while there is no single agreed-upon definition, the European Network of Living Labs (ENoLL) defines them as user-centred, open innovation ecosystems that use a co-creation approach to solutions or service development in real-life settings. [7]
  For example, the Smart Mobility Living Lab.
- **Proving grounds:** predominantly used in the context of demonstrators involving the automotive industry, proving grounds typically comprise open-access, private realm, controlled environment facilities to enable the testing of new solutions. For example, the Millbrook Proving Ground.
- **Test networks:** open-access communication networks, typically available for non-commercial purposes, to enable the prototyping of new products and services. For example, the Things Connected LoRaWAN™ network.
- **Virtual demonstration platforms:** digital representations of real locations that enable collaborative, virtual experimentation, improved planning and informed decision-making.[8] For example, the Virtual Singapore platform.

For the purpose of this report and for ease of ensuing discussion, the underlying infrastructures and platforms listed above will collectively be referred to under the more general term of test bed environments.

While demonstration projects are often led by closed consortia, test bed environments are typically more open in nature, allowing a wide range of stakeholders to make use of the facilities at various stages of operation. Access is usually provided in return for financial or material contributions.

To put this into context, the GATEway connected and autonomous vehicle demonstration project was carried out in the Smart Mobility Living Lab in London. This city-based test bed environment also plays host to a number of other demonstration projects, including the MOVE_UK project.

While numerous test beds have been created and countless demonstration projects have been carried out around the world, relatively few have led to the scaling and operationalisation of smart city solutions. Despite this, huge sums of money continue to be invested in these initiatives.

For this reason, the Future Cities Catapult has conducted an extensive research exercise to understand what can be learned from previous smart city demonstrators in the hope that these insights will help future demonstrators to avoid the mistakes made by those before them and support them in delivering successful outcomes.

This report aims to:

- Provide a view of the global smart city demonstrator landscape
- Identify trends with regards to aims, scale, funding sources, use-cases and locations of demonstrators
- Analyse common challenges experienced by demonstrators in a range of market verticals
- Discover and share what lessons have been learned during the planning, delivery and management phases of previous demonstrators
- Highlight innovative ways in which demonstrators have overcome the challenges they have experienced

2
THE GLOBAL DEMONSTRATOR LANDSCAPE

2.1 METHODOLOGY

Due to the huge number of demonstrators both within the UK and worldwide, we have not attempted to identify all examples. We have tried to be relatively comprehensive in identifying demonstrators within the UK and have aimed to include prominent flagship programmes internationally. This initial piece of research was conducted using a desk-based research approach drawing on practitioner literature and market studies, along with input from industry experts at a series of workshops.

We have used a number of parameters to bound our research.

Firstly, we have taken a view of the market verticals and use-cases most pertinent to the smart city agenda. This has led us to focus our research on the following areas:

City Services: including traffic, parking, lighting, waste management and public safety demonstrators.

Smart Utilities: including smart meters and smart grids demonstrators.

Smart Healthcare: including assisted living, remote health and preventative health demonstrators.

Connected and Autonomous Vehicles: including driver assistance and various levels of SAE autonomy demonstrators.

Last Mile Supply Chain and Logistics: including fleet management and drone delivery demonstrators.

Connectivity and Data: including IoT, LoRaWAN™ and 5G test networks and various innovative city-focused data platforms.

Secondly, within each of these verticals, specific demonstration projects and test bed environments were identified using the following parameters:

Size: we have predominantly focused on large-scale demonstrators, categorised as those receiving initial funding of over £1m or those covering large geographical areas.

Demonstrator location: those based in the public realm, as opposed to those located on private property or campuses, have been prioritised. Additionally, those utilising brownfield sites have also been prioritised, as these demonstrators are likely to provide a better understanding of the complexities associated with retrofitting and working within existing boundaries.

Status: we have limited our view of demonstrators to those that are currently in delivery, are operational or have been completed within the last 10 years. This ensures that solutions discussed are relevant to the cities of today.

Geographical spread: we have aimed to present a good spread of demonstrators, both within the UK and internationally.

A small number of demonstrators that do not conform to these criteria have been included due to the interesting insights they bring to the subsequent discussion.

Using this methodology, we have identified over 90 demonstrators within the UK and approximately 60 demonstrators internationally.

The following sections will provide an overview of these demonstrators and will identify major trends that have emerged. It should be noted that a number of demonstrators consisted of projects spanning multiple market verticals. In these cases, we have placed the demonstrator in the vertical in which the majority of its projects reside. In a minority of cases, we have duplicated the demonstrator entry to ensure it is properly represented.

2.2 CITY SERVICES DEMONSTRATORS

The past five years have seen an explosion in the number of smart city demonstrators aiming to deliver solutions that will increase the efficiency and effectiveness of everyday city services. This has led to the creation of some of the largest and most costly demonstrators included in this report.

The most common use-cases demonstrated were found to be:

- Smart traffic management: the use of sensors, cameras and networked traffic signals to regulate and optimise the flow of traffic through a city in response to demand. Aimed at reducing congestion, pollution and accidents.

- **Smart parking:** the use of sensors, cameras and data to deliver solutions such as smart ticketing and access control, revenue management, parking guidance and automated slot management.

- **Smart street lighting:** the replacement of current streetlights with more efficient LED technology, along with the integration of a communications platform enabling the integration of other assets such as electricity and water meters, traffic lights, parking meters and environmental sensors.
- **Smart waste management:** use of analytics, routing algorithms and sensors to reduce waste and increase the reuse and recovery of materials amidst growing populations and resources scarcity.

Within the UK, notable examples of city services demonstrators are the Future City Glasgow, Manchester CityVerve and MK:Smart projects. These projects demonstrated a range of use-cases in the city services domain, as well as several use-cases that cross into other areas such as preventative health applications.

These large-scale, multiple use-case demonstrators were typically funded jointly by government and industry, with public-sector funding being provided by the Department for Digital, Culture, Media and Sport (DCMS), Innovate UK and the Higher Education Funding Council for England (HEFCE).

Several other cities in the UK have succeeded in launching large pilots which focus on one specific use-case – for example, Cardiff City Council ran a smart parking pilot in a subsection of the city, which has now progressed to full city-wide implementation.

Across Europe, the European Commission has funded a number of large demonstration projects, including Triangulum, Synchronicity and Grow Smarter, which aim to demonstrate, showcase and build the market for smart city solutions. Cities in the Netherlands, Denmark and Finland have also experienced success in using arm's length organisations to create multi-use, city-based test bed environments, which enable the demonstration of solutions and services linked to specific city challenges. For example, the Smart Kalasatama living lab has been established by Forum Virium, an arm's length organisation of the City of Helsinki, and the Copenhagen Street Lab has been established by the Copenhagen Solutions Lab in collaboration with the City of Copenhagen.

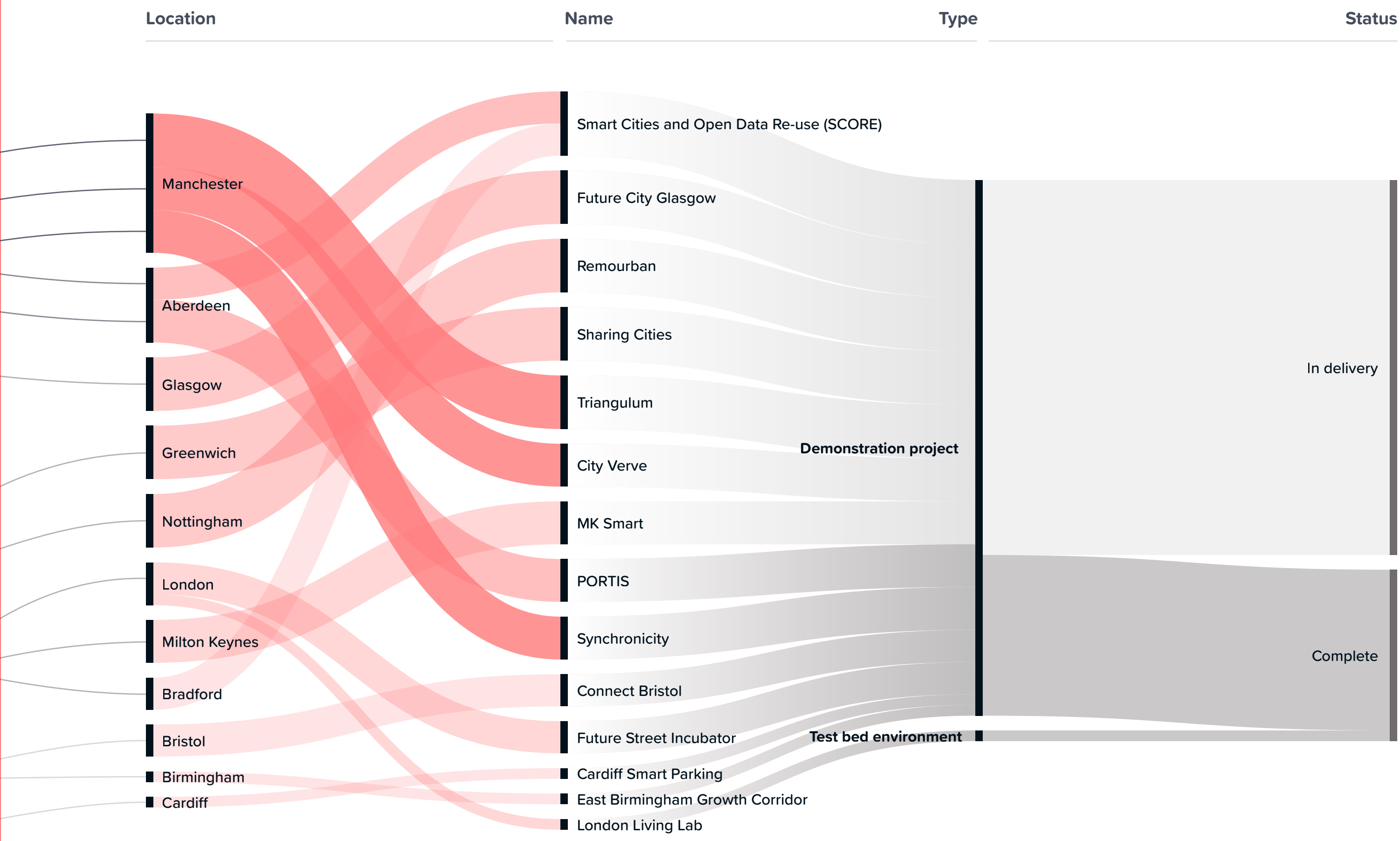
Outside of Europe, the smart city agenda is rapidly gaining pace. In 2015, the Indian government launched their Smart Cities Mission, a USD 7.2 billion initiative aiming to create 100 Indian smart cities by 2020. [9] Similarly, 290 Chinese cities have initiated smart-city pilot projects and more than 300 cities have signed smart city construction agreements with IT companies. [10]

The U.S. Department of Transportation launched a Smart City Challenge which asked mid-sized cities across America to develop ideas for an integrated smart transportation system. The USA and Canada are also seeing increased private-sector investment in the smart city agenda, as illustrated by Sidewalk Lab's recent announcement of their involvement in Toronto's Eastern Waterfront redevelopment.

Finally, Middle Eastern countries, including the United Arab Emirates, Qatar and Saudi Arabia, have invested billions of dollars into retrofitting existing cities and creating new smart cities. These projects are typically broader greenfield city construction projects, with elements of the smart city services agenda included.

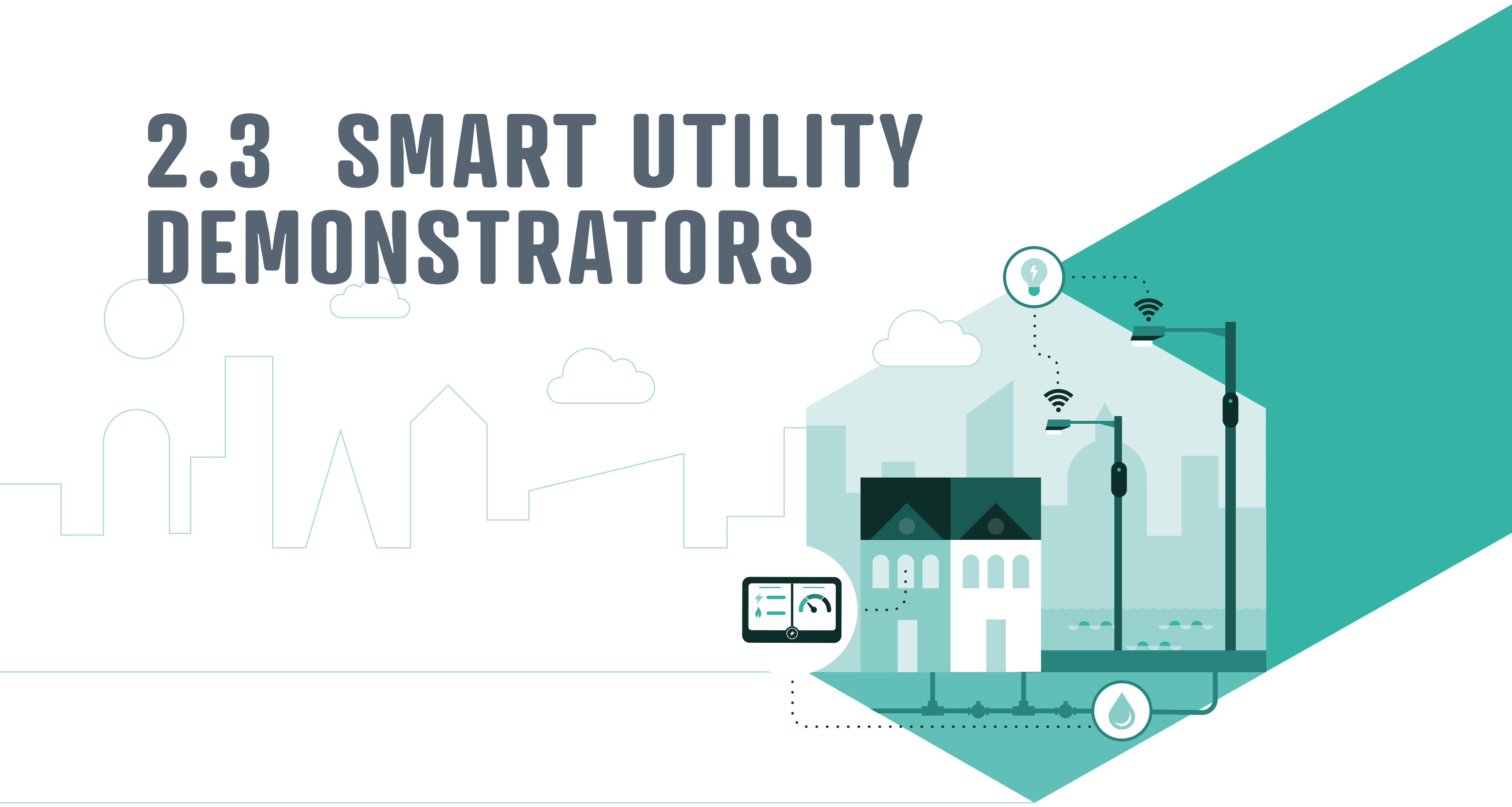
See City Services Demonstrators map on pages 24-25.

CITY SERVICES DEMONSTRATORS



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.3 SMART UTILITY DEMONSTRATORS



The water and energy sectors are currently facing challenges in meeting increased demand and environmental targets.

Demand for energy is rising due to the anticipated growth in adoption of electric vehicles and the use of electricity for heating. Furthermore, as traditional sources of energy supply are replaced by new ones, supply and demand are becoming more dynamic, making energy systems more difficult and complex to manage. Demand for water is also outstripping supply.

Compounding these challenges, environmental considerations are becoming more important, with European Commission legislation requiring member states to reduce greenhouse gas emissions by 80% (compared to the 1990 level) by 2050.[11]

Therefore, the drivers at the heart of smart utility demonstrators and solutions are the need to reduce energy consumption and carbon emissions, lower the costs for consumers and ultimately reduce the requirement to expand networks to cope with increases in demand.

The most common applications piloted in demonstrators were found to be smart meters, smart grids and dynamic energy marketplaces. There was also a growing trend to deliver energy as a service to consumers, rather than as a commodity.

Our research has revealed a wide variety of smart utility demonstrators in the UK, ranging from discrete projects aimed at piloting smart micro-grid solutions and dynamic energy marketplaces, to those that create test bed facilities in the public or private domain to allow the testing of numerous smart utility applications.

In the energy sector, private-land test beds such as the Keele Smart Energy Demonstrator and the Power Networks Demonstration Centre provide research and development (R&D) facilities to enable highly realistic and accelerated technology testing of smart grid solutions, without the constraints of operating on public networks.

Demonstration projects such as the Customer-Led Network Revolution, FALCON Smart Grid and Low Carbon London used public energy networks to establish large-scale smart grids and demonstrate innovative consumer services and commercial arrangements between key stakeholders in the electricity industry.

In the water sector, Anglian Water and Thames Water have designated parts of their live networks as test beds to enable the demonstration of future water-monitoring solutions. There are several instances where demonstrations on these networks have led to the procurement of full operational solutions.

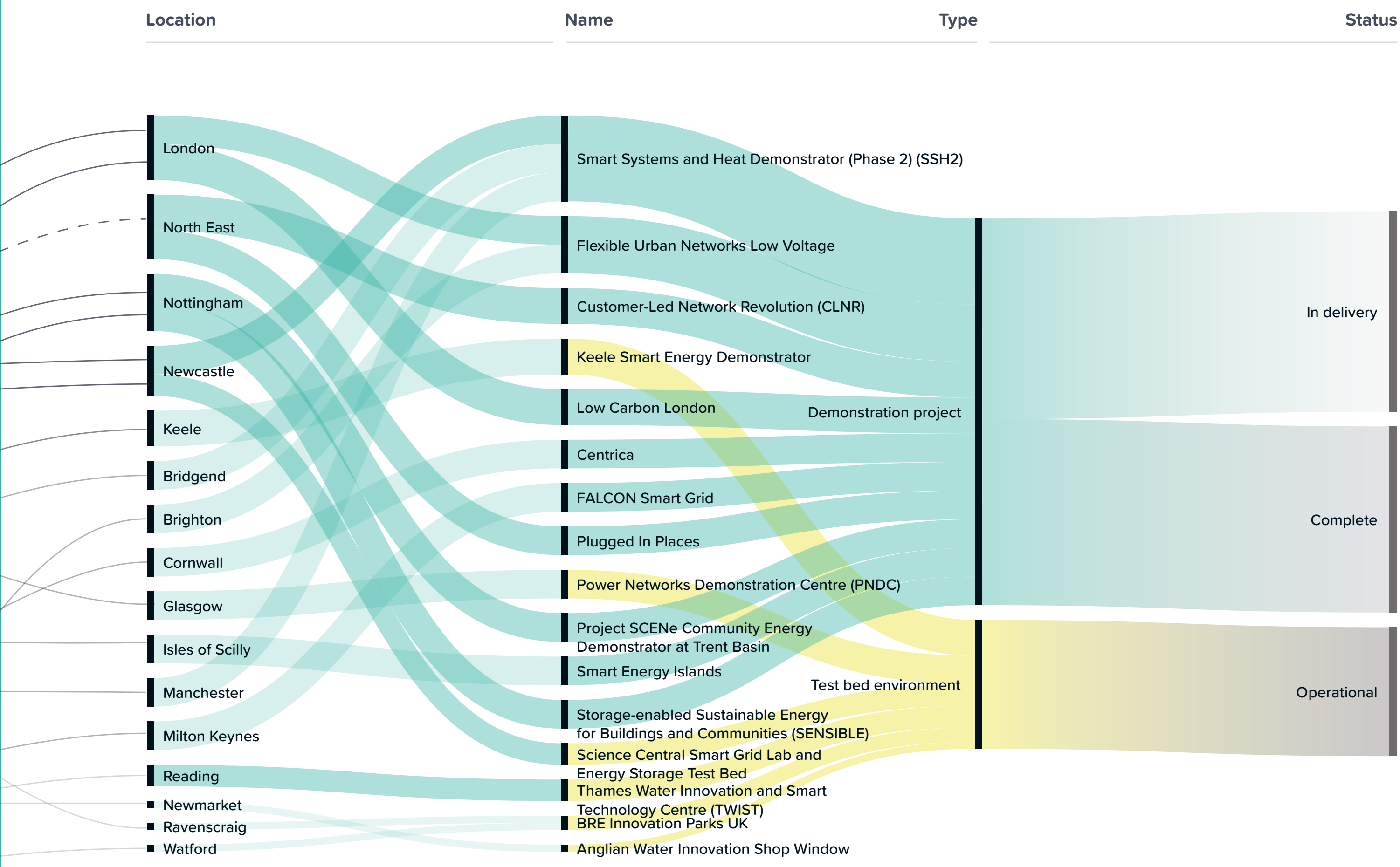
In terms of funding sources, the utility sector displayed considerable variety. Funding for demonstrators was received from the European Regional Development Fund, Horizon 2020, City Deals, the Department for Business Energy and Industrial Strategy (BEIS) and Ofgem's Low Carbon Networks Fund. Furthermore, distribution network operators (DNOs) were also able to fund their own demonstration projects by leveraging Ofgem's Network Innovation Alliance (NIA). The NIA is set by each operator as part of their price control allowance which can be used to fund smaller technical, commercial or operational projects that have the potential to deliver financial benefits to licensees and customers. [12]

In 2017, the Department of Business, Energy and Industrial Strategy (BEIS), in collaboration with the Office for Low Emission Vehicles (OLEV) and Innovate UK launched an Innovation in Vehicle-to-Grid (V2G) systems competition which provides £20m to real-world demonstrators to develop future V2G products, services and knowledge. [13]

The international smart utility demonstrator landscape is punctuated by a number of very large electrical smart grid projects which aim to enable the incorporation of renewable energy sources and cope with the stress that electric vehicle charging places on the existing energy infrastructure. These demonstrators were often funded by national or city governments.

See Smart Utility Demonstrators map on pages 28-29.

SMART UTILITY DEMONSTRATORS



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.4 SMART HEALTH DEMONSTRATORS

Ageing populations are leading to an increase in age-related health conditions and demand for adequate social care, creating challenges for healthcare providers. In the UK, the population aged 65 and over is expected to rise from 18% in 2016 to 24.7% by 2046, and this trend is replicated in the majority of developed countries worldwide.[14] In order to handle this increase in demand for health services, there is a growing focus on using demonstrators to:

- Design buildings and communities that are appropriate for all ages
- Enable the self-monitoring of chronic conditions
- Deploy assisted living technologies to support people to stay in their homes longer

Over the past 10 years, the UK has launched a number of prominent large-scale smart health demonstration projects, including the Delivering Assisted Living Lifestyles at Scale (DALLAS) programme and the Whole System Demonstrator, which is believed to be the largest randomised controlled trial of telecare and telehealth in the world to date. More recently, NHS England has initiated a Healthy New Towns programme and a number of IoT Test Beds.

The UK continues to strive for excellence in the smart health domain with the establishment of the £40 million National Innovation Centre for Ageing in Newcastle.[15]

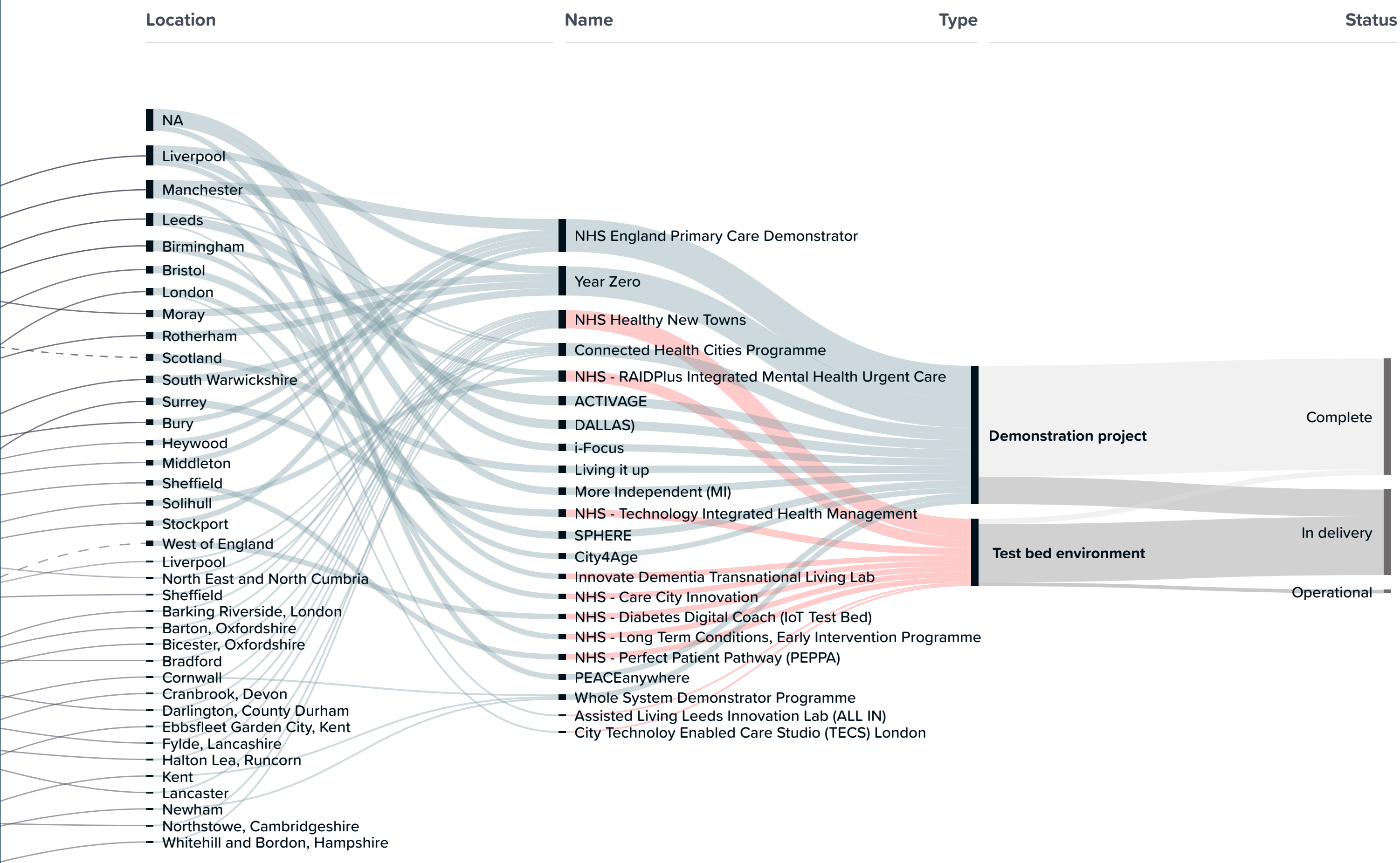
In Europe, the European Commission has funded several large smart health demonstrators, such as the ACTIVAGE demonstrator, which aims to support the piloting of IoT-based active and healthy ageing solutions, and the RAMCIP demonstrator, which aims to develop assistive robotics solutions for the elderly and those suffering mild cognitive impairments.

Furthermore, a number of Asian countries, including Singapore, Japan and Thailand, are also expected to be challenged with the effects of ageing populations in coming years, and hence have launched their own demonstrators involving assistive technologies, robotics and telehealth initiatives.

More broadly, the wider health demonstrator landscape is typified by a number of incubators, accelerators and technology clusters which support the creation of solutions by businesses, who then run smaller-scale pilots with local health providers. Examples include the Copenhagen Health Tech Cluster, the Paris e-Health Incubator, the Digital Health London Accelerator and the Digital Health Breakthrough Network in New York.

See Smart Health Demonstrators map on pages 32-33.

SMART HEALTH DEMONSTRATORS IN THE UK



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.5 CONNECTED AND AUTONOMOUS VEHICLE DEMONSTRATORS

In recent years, there has been a rapid worldwide proliferation in the number of connected and autonomous vehicle (CAV) demonstrators. However, while research and development projects have become practically countless, commercial deployments remain rare.

Our analysis has shown that the focus of CAV demonstrators spans the SAE autonomy-level spectrum, ranging from those aiming to deliver driver assistance (level 1) use-cases to those focused on high automation (level 4) demonstrations in real-world conditions. Specifically, the most common use-cases being demonstrated include:

- **Driver Assistance:** advanced vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems that use on-board sensors and connections to other vehicles and back-office systems to improve safety as well as reduce congestion.
- **SAE Autonomy level 3 (conditional automation):** described as "an automated driving system that handles all aspects of the dynamic driving task, with the expectation that the human driver will respond appropriately to a request to intervene".
- **SAE Autonomy level 4 (high automation):** defined as "an automated driving system conducting all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene". [16]

In addition to demonstrating technical automation capabilities, the majority of projects also seek to understand and address the potential barriers to large-scale CAV deployment, such as legal, societal and regulatory challenges.

The CAV agenda is a key focus area for the UK, with the 2017 Industrial Strategy stating that the government wants to see fully self-driving cars, without a human operator, on UK roads by 2021. This ambition has been reinforced by the establishment of the Centre for Connected and

Autonomous Vehicles. Set up in 2015, the centre is tasked with working across government to support market creation for CAVs. It has since provided over £250m in funding for CAV demonstration projects and test beds. The most recent round of investment funded the creation and expansion of real-world test environments in the West Midlands, Oxfordshire and Bedfordshire. This new testing ecosystem will be coordinated by MERIDIAN, a new government-backed and industry-led hub to develop CAV technology in the UK. [17]

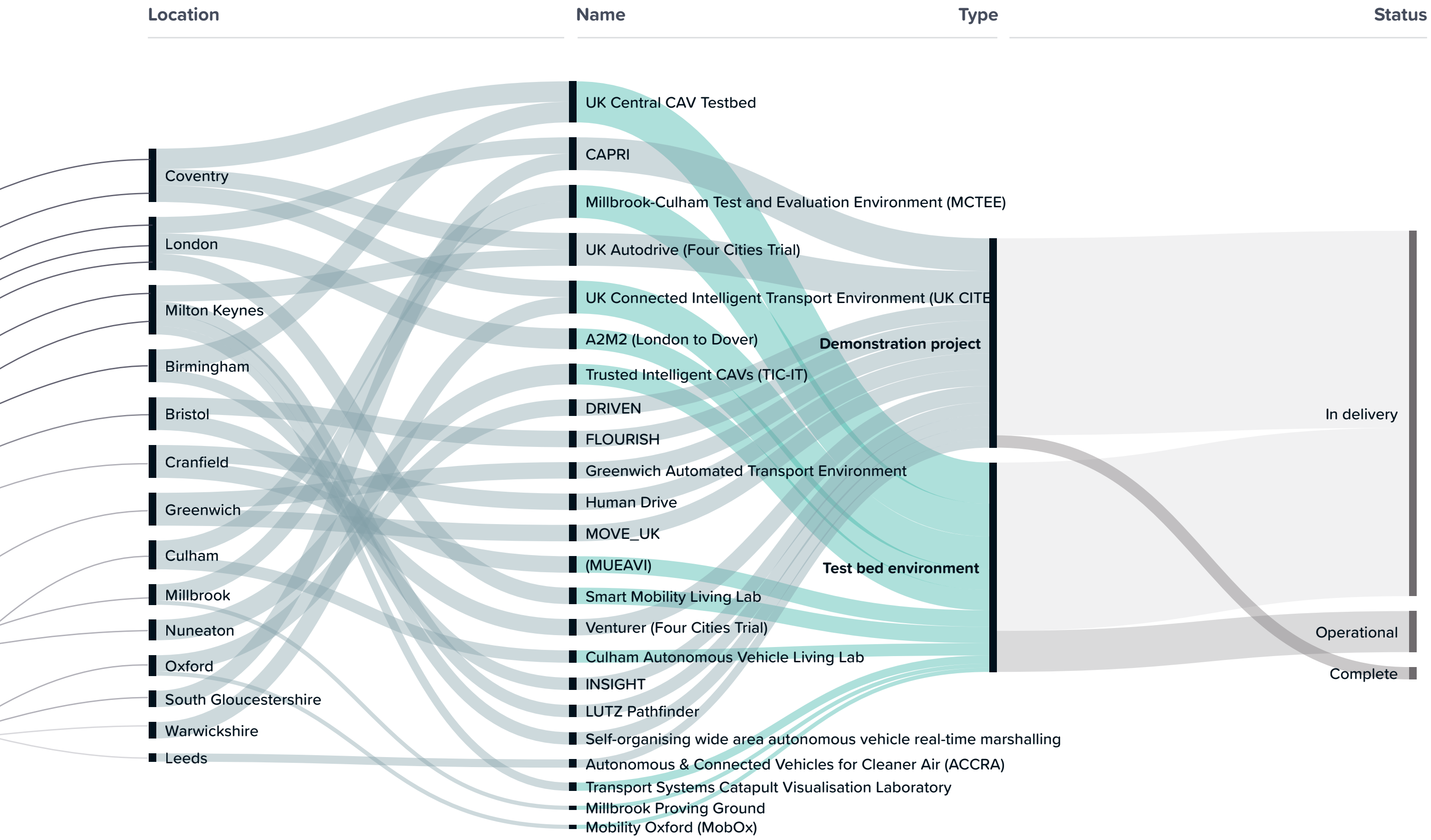
Within the UK, a number of geographical areas are emerging as front runners in the real-world testing and deployment of CAVs. Projects and test beds are being clustered in the following areas:

- **London:** The Smart Mobility Living Lab is based in Greenwich and Stratford. This lab hosts various CAV projects including the GATEway and MOVE_UK trials.
- **Milton Keynes:** The City is pioneering the use of autonomous pods to create new transport options as part of the UK Autodrive, SWARM and LUTZ Pathfinder projects. The Millbrook proving ground is also located near the city.
- **Coventry:** The City plays host to the UK Central CAV test bed as well as the large UK CITE and UK Autodrive projects.
- **Bristol:** The city and the wider South Gloucestershire area host the Venturer and FLOURISH CAV projects.
- **Oxford:** Roads within and between Oxford and London will be used to host SAE level 4 autonomous vehicle journeys as part of the DRIVEN project by 2019. The Culham Autonomous Vehicle Living Lab is also nearby.

Internationally, a number of countries are pushing ahead with the CAV agendas, including Singapore, Germany, USA, China, Korea and Sweden. Huge numbers of private-land test beds have been established, including the National Intelligent Connected Vehicle Testing Demonstration Base in Shanghai, the K City test bed in South Korea and the M City test bed in Michigan, USA. More recently, the number of instrumented roadways and on-road trials has increased dramatically, with the USA, Germany and Sweden leading the way.

See Connected and Autonomous Vehicle map on pages 36-37.

CONNECTED AND AUTONOMOUS VEHICLE DEMONSTRATORS



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.6 LAST MILE SUPPLY CHAIN AND LOGISTICS DEMONSTRATORS

Freight distribution is an increasingly important part of modern city life. Most goods consumed in our cities originate externally and must be transported into urban centres. Trucks and vans remain the dominant transport mode as they are perceived to be most suitable for delivering goods to specific destinations within complex urban street systems. However, the rising numbers of freight vehicles are causing economic, social and environmental impacts in the form of congestion and noise and air pollution. [18]

In response to these impacts, investments are being seen in a range of demonstrators aiming to pilot the following technologies and solutions:

- **'Green' delivery vehicles:** in the form of electric vans and bicycle delivery systems to reduce emissions.
- **Advanced algorithms and analytics:** covering the distribution, storage and transport of goods, to help delivery companies optimise aspects of their operations in areas such as fleet management and routing.
- **Delivery drones and robots:** enabling companies to provide extremely fast and flexible delivery services, with smaller environmental impacts at potentially lower prices. [19]

The primary focus of demonstrators, both in the UK and globally, has been and remains the introduction of electric freight vehicles and other environmentally friendly goods delivery options.

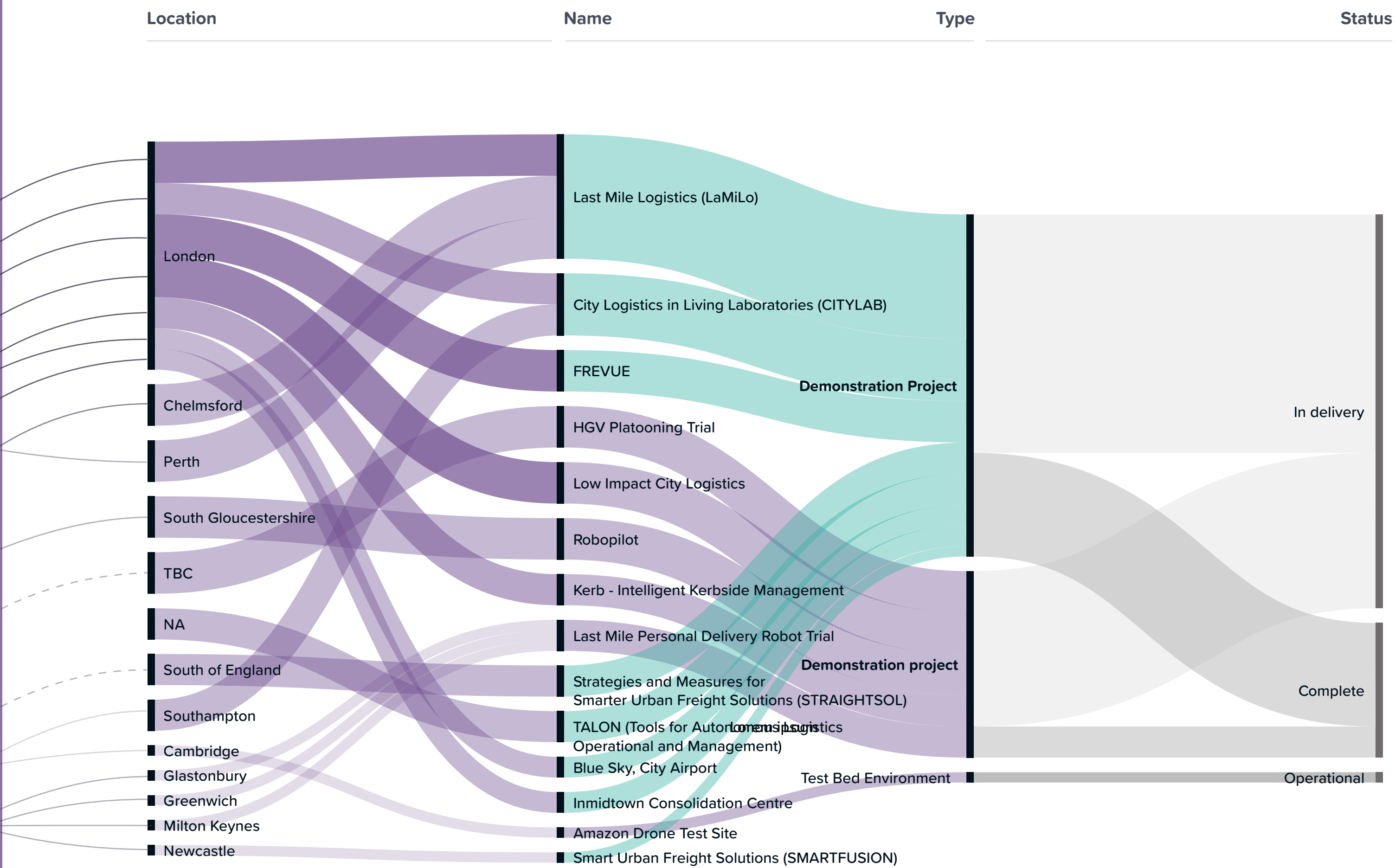
In Europe, this focus was established in the early 2000s with the launch of the European Commission's CITY–VITAlity–Sustainability (CIVITAS) initiative, which provided funding for projects and acted as a convening forum, bringing cities together across Europe to design and test solutions around urban freight management. This focus has been further reiterated through the formation of the Global Green Freight Action Plan and the Green Freight Asia Initiative.

The focus on low-emission urban freight continues, highlighted by the 2017 announcement from the Office of Low Emission Vehicles (OLEV) regarding its allocation of £20m in funding for 20 trial projects to demonstrate new technologies and to encourage widespread introduction of low- and zero-emission vehicles into UK commercial fleets. [20]

Emerging technology solutions such as drones and delivery robots are starting to be demonstrated in the public domain. These smaller-scale demonstrators are predominantly driven by the private sector, with little funding coming from public sources. Examples include Starship Technologies testing autonomous delivery robots on the pavements of Milton Keynes and Greenwich, and UPS testing a delivery drone that launches from the top of a UPS van and autonomously delivers a package to a home before returning to the vehicle while the delivery driver continues along the route to make a separate delivery. [21]

See Last Mile Supply Chain and Logistics map on pages 40-41.

LAST MILE SUPPLY CHAIN AND LOGISTICS DEMONSTRATORS



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.7 NEXT-GENERATION CONNECTIVITY AND DATA DEMONSTRATORS

Emerging smart city solutions such as smart city services applications, smart grids and smart healthcare services often rely on the use of connectivity networks. In many cases, the requirements of these smart solutions cannot be met with today's connectivity networks. New types and combinations of underlying connectivity infrastructures are required to meet unprecedented needs in terms of agility, reliability, security, scalability and partnerships. [22]

Realising that a reliable communication network is an essential part of a fully integrated, truly connected smart city, a number of demonstrators have emerged that are focused on enabling and underpinning a wide range of use-cases, rather than being specific to one.

In the UK, demonstrators such as Bristol is Open and the Things Connected programme aim to provide open, experimental, next-generation ICT platforms that can be used by companies and developers to build and test a wide range of applications. Bristol is Open provides combinations of Wi-Fi, 3G, 4G, LTE, early 5G and radio frequency mesh networks, while Things Connected provides a free LoRaWAN™ network.

In some cities, basic underlying connectivity infrastructure is not yet in place. Our research has uncovered some innovative approaches to deploying fibre and wireless networks, along with some novel methods of enabling new services to be developed on top. These examples will be discussed in more detail in the lessons learned section of this report.

As the commercial rollout of 5G approaches, several test beds have been created that aim to provide businesses and entrepreneurs with access to emerging 5G technologies. In the UK, two 5G test beds have been funded by local enterprise partnerships (LEPs) based on the potential of new technologies to catalyse business growth and local economic development. However, these test beds are currently deployed within buildings or on closed sites, rather than real-city environments.

The government has a clear ambition for the UK to be a global leader in the next generation of mobile technology. The 5G Innovation Centre has been established, bringing together leading academics and key industry partners to help define and develop the 5G infrastructure that will underpin the way we communicate, work and live in the future.

In July 2017, the government announced that three universities had been awarded £16m in funding to develop cutting-edge 5G test networks. This funding included plans to deliver an end-to-end 5G trial in early 2018.[23]

In October 2017, DCMS launched its 5G Testbeds and Trials Programme which provides up to £25 million in funding to encourage the development of a UK '5G ecosystem' with technology and deployment, test beds and trials to stimulate the development of 5G use-cases and business models.[24]

Internationally, 5G trials are continuing at pace in Japan, Germany, China, South Korea, USA, France and Sweden. These small-scale trials are invariably led by respective large telecommunication providers such as AT&T, NTT DoCoMo, Deutsche Telekom, KT, Orange, Ericsson and China Mobile. Open-access, city-based 5G test beds have been established in Sweden (Urban ICT Arena) and Germany (5G Berlin).

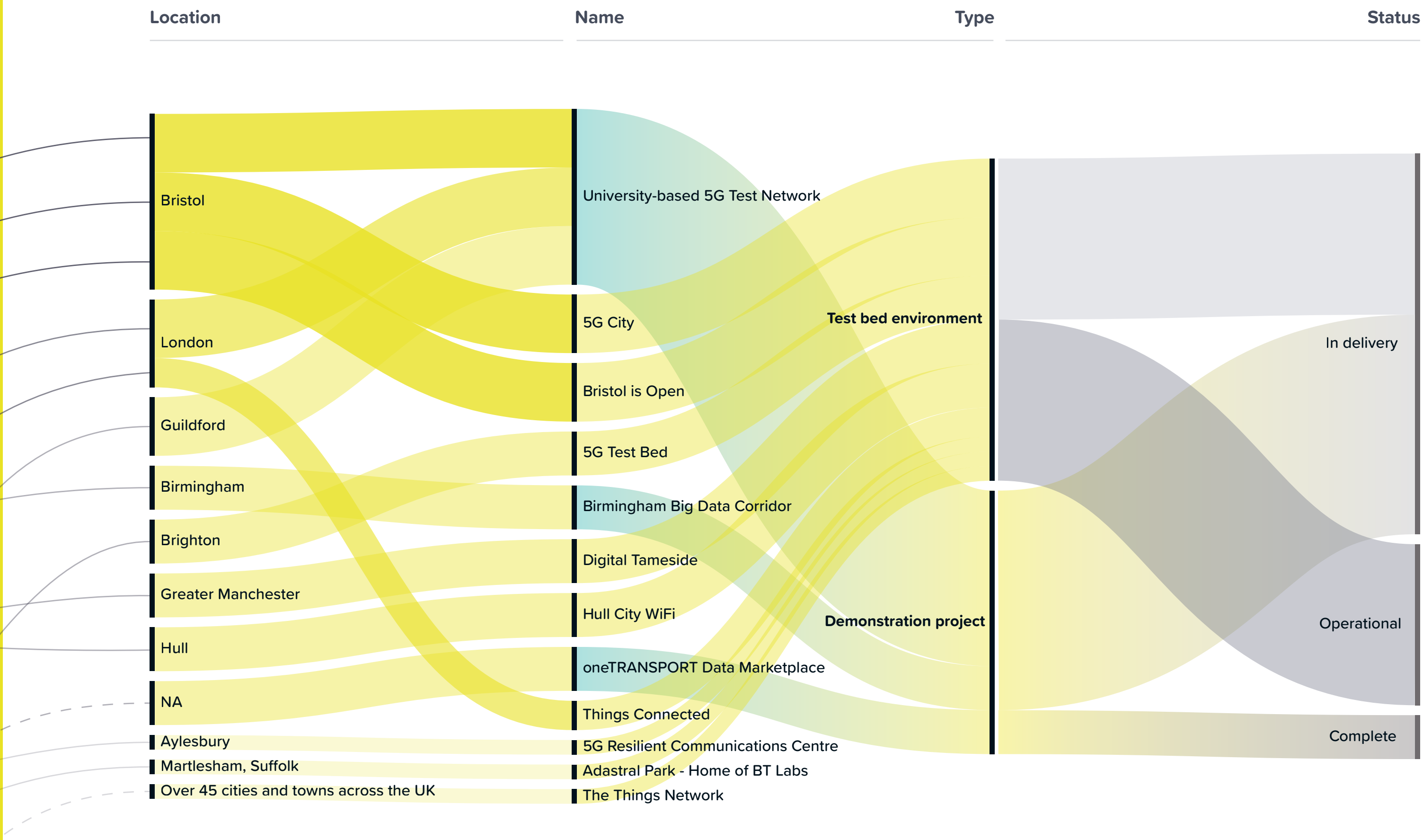
If communication networks are the critical infrastructure for smart cities, then data is the critical information. In the same way as a smart city requires ubiquitous connectivity, it also requires access to various open and closed, public and private data sources.

The creation of open data hubs is becoming commonplace in the UK and abroad, with numerous cities launching their own in recent years. Examples include the London Data Store, Data Mill North and Birmingham Data Factory.

Taking this concept one step further, Singapore has created its Virtual Singapore platform which provides a collaborative, dynamic data platform for public, private, research and citizen use. This platform acts as a virtual test bed and experimentation environment. The UK is now seeking to build a similar platform with its UK Digital Twin pilot project.

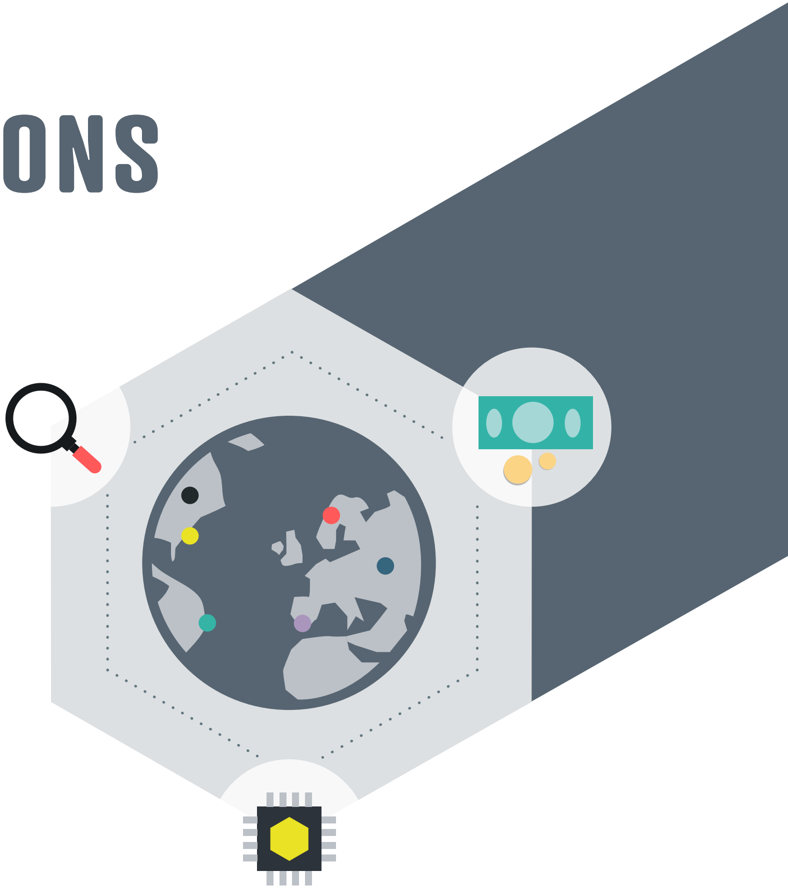
In terms of demonstrators, our research has identified a growing global trend around creating data marketplaces. The City Data Exchange in Copenhagen is a software-as-a-service solution that makes it possible to purchase, sell and share a broad range of public and private data types. In the UK, the oneTRANSPORT Data Marketplace demonstrator aims to gather data about the transport operations of multiple towns and cities and make this available using a data-licensing approach.

NEXT-GENERATION CONNECTIVITY AND DATA DEMONSTRATORS



Vertical line size = scale of investment (under £1m, Under £5m, £5m – £20m and £20m – £50m)

2.8 OBSERVATIONS ON THE GLOBAL SMART CITY DEMONSTRATOR LANDSCAPE



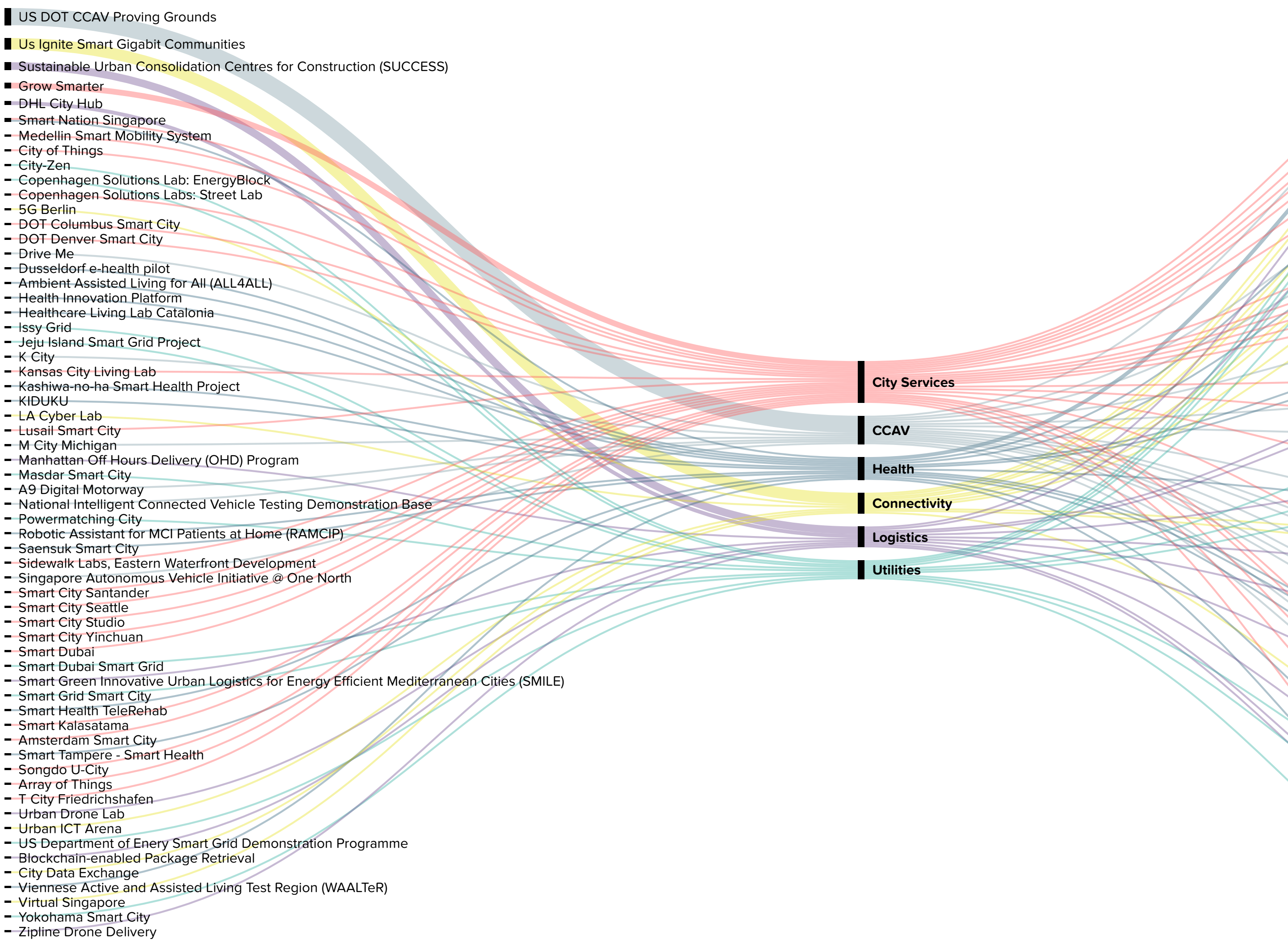
Based on our analysis of the global smart city demonstrator landscape, the following observations have been made:

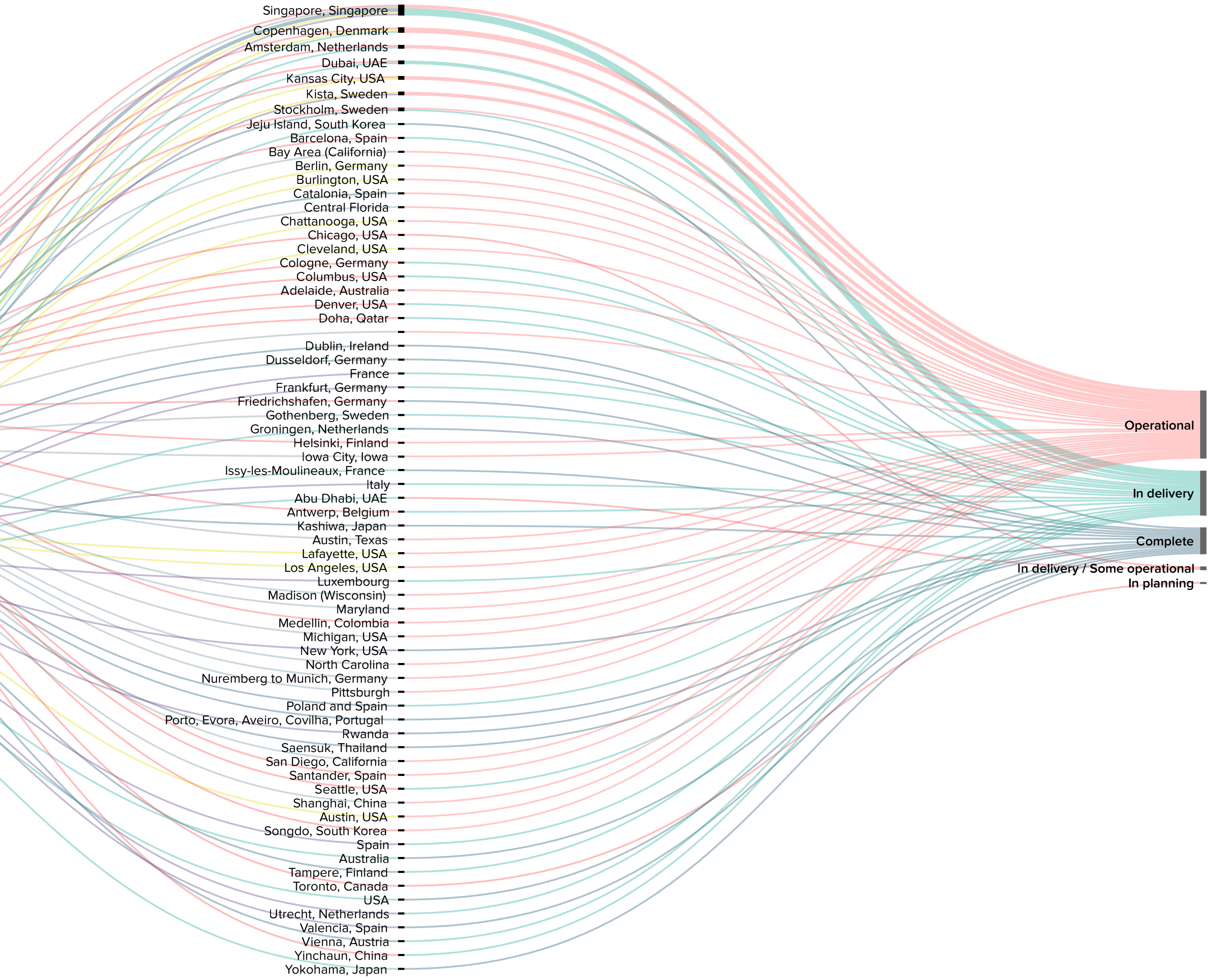
Focus of demonstration projects: There appears to be a lot of focus and funding designated to the creation of trials and pilots aimed at demonstrating technical functionality in real-world environments. While these projects are undoubtedly necessary, there is comparatively little focus on creating projects and test beds aimed at enabling the demonstration of commercial viability at scale and the required business models that will lead to transactions in the market. In a UK context, interviewees felt that this had resulted in demonstrators succeeding in accelerating the development of solutions up to a certain technology readiness level (TRL 6), but it was felt that after this point, progress stalled. It should be noted that this trend did not apply to the utility market.

Technology-led demonstrators: Despite the continuous rhetoric around the smart city agenda seeking to solve city challenges, many demonstrators have ended up as technology demonstrations. Technology is fundamental to a smart city, yet it should serve as a means to an end, rather than being the focus. A need has been identified for societal challenge-based demonstrators that place city issues front and centre – for example, a congestion-focused demonstrator could involve the demonstration of multiple solutions across market verticals, such as smart traffic management (city services), drone delivery (logistics) and autonomous public transport systems (CAV). These could then be assessed in the context of how well they solve a particular challenge, rather than whether 'the technology has functioned as expected'. This would also help demonstrators be seen as strategic projects leading to the creation of procurable solutions, rather than tools for publicity.

Funding of demonstrators: The majority of demonstration projects are funded using a grant-based model and create single-use, time-limited testing infrastructures. Test bed environments are often funded by grants and few have plans for self-sustainability. This grant-based funding model causes projects to end abruptly due to short time frames, limits continuity between project phases and does not expect the demonstrator to generate any income to recover the initial investment, leading it to be thought of as purely a research infrastructure. An alternative to this model could be a shift to a recoverable investment-based demonstrator model that aims to create multi-use, enduring infrastructure that allows for continuity in solution development, prolonged impact measurement and benefits realisation, and ultimately, transactions in the market.

THE GLOBAL SMART CITY DEMONSTRATOR LANDSCAPE




Singapore, Singapore
Copenhagen, Denmark
Amsterdam, Netherlands
Dubai, UAE
Kansas City, USA
Kista, Sweden
Stockholm, Sweden
Jeju Island, South Korea
Barcelona, Spain
Bay Area (California)
Berlin, Germany
Burlington, USA
Catalonia, Spain
Central Florida
Chattanooga, USA
Chicago, USA
Cleveland, USA
Cologne, Germany
Columbus, USA
Adelaide, Australia
Denver, USA
Doha, Qatar
Dublin, Ireland
Dusseldorf, Germany
France
Frankfurt, Germany
Friedrichshafen, Germany
Gothenberg, Sweden
Groningen, Netherlands
Helsinki, Finland
Iowa City, Iowa
Issy-les-Moulineaux, France
Italy
Abu Dhabi, UAE
Antwerp, Belgium
Kashiwa, Japan
Austin, Texas
Lafayette, USA
Los Angeles, USA
Luxembourg
Madison (Wisconsin)
Maryland
Medellin, Colombia
Michigan, USA
New York, USA
North Carolina
Nuremberg to Munich, Germany
Pittsburgh
Poland and Spain
Porto, Evora, Aveiro, Covilha, Portugal
Rwanda
Saensuk, Thailand
San Diego, California
Santander, Spain
Seattle, USA
Shanghai, China
Austin, USA
Songdo, South Korea
Spain
Australia
Tampere, Finland
Toronto, Canada
USA
Utrecht, Netherlands
Valencia, Spain
Vienna, Austria
Yinchaun, China
Yokohama, Japan
Operational
In delivery
Complete
In delivery / Some operational
In planning

3

CHALLENGES AND LESSONS LEARNED FROM DEMONSTRATORS

Once a comprehensive list of demonstration projects and test bed environments had been established, our research sought to understand the challenges experienced by those delivering and operating demonstrators. This report seeks to highlight lessons learned around these challenges, as well as any innovative and replicable approaches demonstrators have employed to overcome them.

To inform this section, the Future Cities Catapult conducted over 40 interviews with smart city demonstrators across the range of market verticals, and held workshops with industry experts. A full list of interviewees can be found in Appendix B.

Challenges and lessons learned fell into four main categories:

Engagement and Access to Assets: Successful execution of demonstrators depends in part on engaging the necessary stakeholders and gaining access to the required assets. Deploying and testing solutions in cities needs engagement and leadership from local authorities, as well as the agreement and support of local citizens. Even when local authorities and citizens are engaged, the ownership of both physical infrastructure and digital assets at the city level is not straightforward, with a multitude of public and private entities developing ownership and jurisdiction over assets. This fragmentation is particularly pronounced in UK cities.

This section will explore the lessons learned and identify best-practice approaches that can be used when trying to engage relevant stakeholders and secure access to city-based assets.

Finance, Governance and Intellectual Property: While the value of innovation test beds and demonstration projects is widely appreciated and there is no shortage of willing participants, there remains a question regarding who has the motivation and resources to fund projects and build the required multi-user test bed environments. By its nature, innovation comes with the associated risk of failure, but these risks need to be taken in order to progress. Furthermore, the complex stakeholder arrangements associated with demonstrators gives rise to complex governance and IP arrangements.

This section will highlight best practice in securing initial funding for demonstrators, along with discussing lessons learned in relation to demonstrator sustainability, governance and IP arrangements between collaborators.

Delivery Capabilities and Skills: Innovative demonstrators are trying to do something new, thus making it difficult to anticipate what skills are required at various stages of delivery and operation. Furthermore, smart city demonstrators tend to require the involvement and cooperation of multiple stakeholders from different economic sectors. These stakeholders have diverse skills, competences, working methods and aims. Bringing these stakeholders together into a productive delivery team requires strong change management and benefits realisation skills, which are rarely considered at the beginning of projects.

This section will provide an overview of the lessons learned by demonstrators with regards to skills and capabilities at various stages of the delivery lifecycle.

Impact Measurement and Scaling: Utilising impact assessment frameworks to understand the benefits delivered by solutions tested in smart city demonstrators is crucial when seeking to justify existing and future investments from the public and private sectors. However, we have seen that standard evaluation frameworks used for large-scale infrastructure projects are not deemed fit for purpose to assess impact and success for innovative demonstrators.

While proving impact is one method of measuring the success of smart city demonstrators, replication and scaling of tested solutions is also seen as a valuable legacy. This can only be achieved through the use of effective knowledge-transfer mechanisms, the use of standards to ensure interoperability and by ensuring the presence of favourable regulatory, legal and policy frameworks.

This section will uncover insights related to the measurement of success of smart city demonstrators and will explore best practice for ensuring the scaling and replication of tested solutions.

ENGAGEMENT AND ACCESS LESSONS LEARNED

A key success factor in the delivery of large-scale demonstrators is securing the buy-in of numerous stakeholders and asset owners. These may range from the local authority to infrastructure operators, public-service providers and citizens. This section explores the challenges experienced and lessons learned when demonstrators have sought to engage affected parties and access required assets.

3.1 LOCAL AUTHORITY CAPACITY AND ENGAGEMENT

Due to the power and assets of local authorities, many large-scale, city-based demonstrators cannot go ahead without their cooperation and participation. Several authorities such as Milton Keynes, Bristol and Coventry are actively putting themselves forward as demonstration 'sandpits' in order to attract inward investment. These authorities have experience in developing and delivering large-scale smart city demonstration projects and therefore require minimal engagement and capacity-building efforts.

It is often inferred that the majority of authorities do not have the capacity or skills to participate in large-scale innovation programmes aimed at applying new technological solutions to city challenges. However, our research has shown that authorities have a range of skills which make valuable contributions to innovation projects – for example, local authorities typically have strong programme and project management skills developed from their experiences delivering more traditional large-scale programmes. They also possess extensive stakeholder management skills developed through their experiences working with diverse partners across the city, such as emergency services, healthcare providers, transport operators, businesses and citizens. In these flat partnership structures, authorities are used to juggling competing interests and agendas.

However, there are a number of challenges that do inhibit the effective participation of authorities in innovation projects. A study by Lucy Zodion on smart city development in the UK revealed that over 80% of councils did not have an appointed lead for smart cities, and many respondents confessed to a low awareness of the topic and what it could mean for them. This has created issues for demonstrators when trying to find the appropriate person to approach in order to initiate demonstration projects.[4]

LESSONS LEARNED

Selection of local authority partners: Selecting the appropriate local authority partner is critical to ensure that demonstration projects can be efficiently and effectively delivered.

In terms of choosing a local authority to participate in innovation projects, interviewees recommended prioritising authorities that are aware of what they do not know and are eager to become knowledgeable partners. It is also important to support the authority in understanding how the project aligns with the challenges the city is experiencing. It was believed that if there is good alignment between the project and the challenges that need to be solved, not only will there be a higher level of commitment to the project, but there will also be a greater likelihood of the solutions being adopted after the demonstration project has finished.

CASE STUDY

AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS (AMS INSTITUTE), AMSTERDAM

The AMS Institute focuses on projects which address the city's specific challenges. The congestion in the city centre and the limited capacity of the road network are major problems in Amsterdam, but the water infrastructure is extensive and has great potential. In close cooperation with the municipality of Amsterdam, AMS Institute – in collaboration with MIT – works on developing the world's first fleet of autonomous boats to run on Amsterdam's canals. The aim is to use these autonomous vessels across the city to transport people and goods, to remove waste from the canals and to create temporary on-demand bridges.

Various approaches have been used to select local authorities for demonstration projects. In many cases, commercial organisations have approached local authorities near their key locations to secure their support for projects. In other cases, open competitions have been used to make an impartial selection.

CASE STUDY

SMART SYSTEMS AND HEAT DEMONSTRATOR (PHASE 2)

The Smart Systems and Heat demonstrator ran a competition to find local authority partners, assessing applicants based on their motivation to understand the project and their capacity to deliver. Having received 10 well-informed bids, the demonstrator selected three authorities with which to work. However, aware that capacity will need to be built in other authorities if the solution is to scale up in the future, the demonstrator runs a 'local authority forum' which keeps over 20 local authorities engaged in the project and informs them of future plans.

Ongoing engagement approaches: When cities are being used as test bed environments, ongoing engagement is required to ensure that the city continues to benefit from its operation and that projects are aligned with the city's challenges. A variety of engagement techniques have been used to achieve this continuity, including regular surveys and workshops.

Interviewees stressed the importance of engaging at multiple levels within a city authority. Strategic decisions makers often require support to understand the details of the projects, while practitioners often understand the finer details but lack the ability to drive home ideas at a political level.

Engagement challenges are further complicated by multiple levels of local governance – for example, the Keele Smart Energy Demonstrator has to engage with parish, borough, city and county councils, who each have different powers and influence. To cope with the levels of engagement required, some demonstrators have appointed a dedicated liaison resource to align, prioritise and enable work to progress efficiently.

CASE STUDY

COPENHAGEN SOLUTIONS LAB (CSL)

The Copenhagen Solutions Lab has established a City Taskforce which aims to:

- Build relationships and onboard key persons from the city administration into the CSL's smart city agenda.
- Produce a pipeline of projects and use relationships to get an overview of demand-side needs and challenges.

The CSL is strategic about who they engage, initially focusing solely on decision makers and budget holders before involving practitioners once strategic priorities have been established. The result of this process has been the formation of an action plan – a catalogue of 25 projects across five themes on which the city would like to work. The CSL can then find appropriate commercial and research partners to make the projects happen.

Resource challenges: Local authorities are already under huge financial and resource pressures, and they therefore struggle to allocate time and resources to innovation projects. This results in local authority workers having to deliver innovation projects alongside their everyday jobs. Additionally, some demonstration projects require skills that local authorities do not usually have in-house.

In response to this challenge, many demonstration projects used funding to bring in additional resources. Technical resources were often scarce within local authorities, and therefore business analysts, solution architects and data scientists were found to be the most common investments. However, there was a reluctance to bring in too many additional resources due to the risk of knowledge loss once project funding had concluded. Wherever possible, it was preferred to utilise existing resources so that knowledge could be retained, and learning could be incorporated into business-as-usual activities.

Engrained and siloed ways of working: Engrained and siloed ways of working within local authorities were reported as causing resistance to the operational and governance changes required to accommodate the smart city technologies used in demonstrators. These siloed structures impede the translation of demonstrated solutions into business-as-usual activities for local authorities. This challenge has been overcome through the use of established change management approaches, incorporating communication, training and coaching initiatives.

CASE STUDY

FUTURE CITY GLASGOW

As part of its Future City Glasgow programme, the city implemented a smart street lighting demonstrator. This was successful in demonstrating desired benefits and is therefore being deployed on a wider scale with funding support from the European Regional Development Fund Strategic Intervention 'Scotland's 8th City, the Smart City'. In order to incorporate smart street lighting into BAU activities, Glasgow is upskilling and changing working processes for a number of departments around this new service delivery method. For example, the lighting team has limited experience of dealing with IT and communications networks, while the IT team has no knowledge of servicing networks on lighting infrastructure. However, with change management and training, the smart infrastructure will be successfully deployed and deliver intended benefits.

3.2 ACCESS TO PHYSICAL ASSETS

The successful implementation of many smart city demonstrators depends, in part, on access to physical assets. These assets consist of the infrastructure and networks that support and enhance the basic operations of a city. For the purposes of this report, they can be categorised into the following areas:

- **Street services: street lighting, EV charging, green spaces, rubbish bins, signage, wayfinding, etc.**
- **Transport services: highways, buses, rail, cycling schemes, taxi services, shared vehicles, etc.**
- **Infrastructure services: water, energy, telecommunications, waste, public Wi-Fi, LPWAN, etc.**
- **Building services: commercial offices, land, housing, government offices, community buildings, hospitals, etc.**

In the UK, the ownership of physical assets at the city level is not straightforward. Private property rights, privatisation of critical infrastructure, outsourcing of city services and a lack of political devolution at the city scale are inhibiting the development of coordinated programmes around joint aims and the implementation of smart city solutions. For example, if Transport for Greater Manchester wanted to introduce an integrated ticketing system, it would need to get the consent of 66 bus operators. [4]

Over 50% of authorities in the UK have entered into private-finance initiative (PFI) agreements to manage the maintenance and operation of various infrastructure assets and public services. [25] Trying to conduct innovation activities under these contracts is extremely difficult due to their long timescales and tight margins. These agreements often extend to include ownership of data produced throughout the assets' operation.

An in-house study of 10 prominent UK cities revealed that ownership models vary significantly from city to city, creating issues not only around securing access to assets, but also around building replicable processes and approaches.[25]

LESSONS LEARNED

Involvement of asset owners: When looking to set up and manage demonstration environments or projects, interviewees recommended ensuring the relevant physical asset owners were involved in the project from the beginning and encouraged selection of asset owners based on their appetite for innovation and willingness to collaborate. Many interviewees stated that if they were unable to secure the participation of the relevant physical asset owners they would not proceed with the project, such is their importance. In instances where asset owners were engaged after the start of the project and were not a member of the core innovation consortium, our analysis has shown that the projects suffered significant time delays and incurred additional costs.

In order to entice competing asset owners to work together, some demonstrators had to conduct the same trials with multiple organisations to gain buy-in. This was the case with the Smart Kalasatama demonstrator who had to conduct multiple smart parking trials with several major private parking operators in order to make the case for a city-wide smart parking solution.

Withdrawal of asset owners: Challenges did not end once participation of asset owners had been secured. As demonstrators progressed, several projects reported the withdrawal of critical asset owners due to risk tolerances being exceeded. For example, one project was forced to find a new demonstration location after the local authority withdrew. The authority's reason for withdrawal was grounded in fears around opening innovation floodgates; if they allowed one demonstration project to take place, would they be expected to allow more projects to take place, and what grounds would they have to refuse similar projects in the future? While this risk aversion was shared by a number of authorities, others were making their assets available for innovation demonstration projects as a means to drive local economic growth. In these cases, the authorities have gone to extraordinary lengths to support the successful implementation of demonstration projects and environments. Respondents recommended seeking out these authorities for early-stage innovation projects.

CASE STUDY

MILTON KEYNES COUNCIL

In order to facilitate the large-scale trialling of an autonomous pod public transport system, the team at Milton Keynes Council needed to secure regulatory changes to enable the pod vehicles to be tested on pavements in the public realm. Understanding that this change would take a considerable amount of time and impact project timescales, the team obtained a special traffic order allowing roadside footways to be reclassified as an extension of the road. They then altered this order to exclude all traffic except pedestrians, disability vehicles and autonomous pods. This allowed the trials to start immediately.

Deployment of equipment onto physical assets: Once participation had been agreed and the project had begun, it was often necessary to deploy new instruments and equipment onto physical assets. In some cases, this was as simple as providing asset owners with a method statement detailing the work task to be completed and outlining the risks, hazards and emergency contacts. In other cases, particularly related to deployments onto operational assets, indemnification agreements around damage and loss of business were required. While still undoubtedly cheaper than building new assets, interviewees were keen to highlight that the legal fees involved in accessing existing physical assets are significant. Furthermore, projects were expected to cover the costs of additional energy usage and maintenance of equipment deployed on assets.

Creation of integrated infrastructures: Further difficulties were identified when trying to combine physical assets to create a multi-functional, integrated demonstration infrastructure. Not only did this involve obtaining the agreement of multiple asset owners, but in many cases the boundaries between these owners did not align. This resulted in projects having to engage several levels of local government as well as multiple healthcare trusts, infrastructure operators and/or public-service providers to create an integrated demonstration area. This complexity was cited as a major driver behind the creation of private-land demonstrators, such as the Keele Smart Energy Demonstrator, where all assets are owned and operated by one organisation. In response to this issue, interviewees recommended paying particular attention to where the boundaries of responsibility lie when selecting demonstration locations, as well as starting with small, temporary pilot zones rather than large areas crossing multiple boundaries.

Access to personal assets: Throughout our interviews, it became clear that the requirement to gain access to physical assets did not stop at public infrastructure. Many of the use-cases explored the access required to people's homes in order to install equipment such as sensors in remote health solutions or smart meters in intelligent utility solutions. This presented its own set of challenges such as recruitment of participants and installation of equipment. These areas will be discussed in more detail in the use research and engagement section.

Management of assets post-project: Interviewees highlighted the need for demonstration projects to consider what happens to deployed equipment at the end of the project and stressed the need to budget for transferring ownership and liabilities or for decommissioning. The approach used by several projects was to give owners three to six months at the end of the project to decide whether they wanted to keep the equipment and access all accompanying responsibilities. If they declined this offer, all equipment would be decommissioned, and the asset would be left in its pre-demonstration state.

3.3 ACCESS TO DATA AND DIGITAL ASSETS

Cisco estimates that digital cities can generate USD 2.3 trillion globally by 2024 through cost savings, improved efficiency and revenue generation.[26] Therefore, in a similar manner to physical assets, demonstrators require access to open and closed, pub lic and private data assets in order to capture the value that smart city solutions can deliver. Furthermore, many smart city demonstrators create data that is useful beyond the scope of the initial project.

LESSONS LEARNED

Use and creation of open data: It has been estimated that open data will generate USD 51 billion of value in cities globally by 2024.[26] In line with this statistic, open data was seen as a valuable asset for smart city demonstration projects and was used extensively. For example, virtual demonstration environments utilised open street map data as a base for their city visualisations, while open traffic and transport data were used in numerous city services applications.

In addition to utilising open data as an input to projects, many demonstrators also sought to publish open data collected through devices they had deployed during their demonstrations. Interviewees were keen to highlight the rigorous process that must be followed to open new data sources, including conducting impact assessments and ensuring compliance with information commissioners. This process typically took upwards of two months and had often not been considered in budgets.

Interviews revealed that published data was often placed into existing or bespoke data hubs in order to make it available to those who wish to engage in the smart city agenda. If creating a new hub, demonstrators made several recommendations, including:

- **Thoroughly researching who the desired users of the hub will be and incorporating this research into the design.**
- **Accounting for operational support of the hub when budgeting.**

CASE STUDY

MK:SMART DATA HUB

The MK:Smart project created a data hub which acquired relevant data from the city, newly deployed sensors and national databases, and it made the data available to the public. The hub was initially designed as a developer-focused hub which would allow individuals with the appropriate technical skills to build their own applications. More recently, MK:Smart are redeveloping the hub into a new portal called MK:Insight, which is expected to provide an environment that is more accessible to non-technical users.

Access to closed data sources: In a similar manner to accessing physical assets, it was recommended that public and private data asset owners were included in the demonstrator consortium from the beginning to maximise the chances of obtaining access to required data.

When seeking to access closed publicly owned data, interviewees recommended utilising existing data infrastructure wherever possible due to the costs and complexity of creating new access pathways and repositories, as well as dealing with associated privacy, trust and ethical concerns. This was the case with the CityVerve demonstrator which was planned to create a new data hub containing healthcare data. Realising this would be extremely complex, they instead used the existing NHS DataWell which could be accessed through their partnership with Manchester University NHS Foundation Trust, minimising costs to the project and time delays due to negotiations.

In order to maximise the value generated from data, participants agreed that it was often necessary to combine public- and private-sector data together to create a more complete picture of a situation.

Securing agreements regarding access to and usage of private-sector data was challenging, even when organisations were partners within the demonstrator consortium. Non-disclosure agreements were the most common way of securing access to discrete sets of data, but organisations remained cautious of the potential legal implications that could result from improper use or data leaks. They also spoke of concerns regarding competitors gaining access to the data.

Collection and use of personal data: Gartner predicts that by 2019, 50% of citizens in million-people cities will benefit from smart city programmes by voluntarily sharing their personal data. [27] Many smart city demonstrator use-cases, such as those involving smart utility meters and healthcare monitors, require the use of personal data. This data is often stored by utility or healthcare providers, but is owned by individuals. Demonstrators were keen to highlight that having access to data does not necessarily mean you can use it for your desired purposes. They also reported that there were rarely processes in place to enable access by third parties or to make sanitised data publicly available.

Our research revealed that individuals were often weary of allowing their data to be used in smart city programmes due to fears of how else it might be used – for example, if they participated in a health-monitoring demonstrator and disclosed an underlying health condition, could this data fall into the hands of insurance companies, thus resulting in higher premiums? Individuals were less wary about providing access to data for short-term, temporary research-driven demonstration projects, but they were reluctant to provide unrestricted access to commercial services. This will become a barrier when looking to scale up operational solutions.

Several demonstrators reported ensuring that personal data was collected and used appropriately by establishing privacy, trust and ethics committees. Other demonstrators with a university as a partner utilised existing academic ethical approval processes to ensure their intended actions were acceptable.

The Powermatching City project overcame this data issue by altering the resolution of data. Individuals were provided with high-resolution data about their energy usage, while the utility companies received lower resolution data. This allowed individuals to feel comfortable about the data they were sharing, while still allowing the utility company to develop its data-driven solution.

The upcoming General Data Protection Regulation (GDPR) should help alleviate some of these individual concerns by requiring data collectors to secure explicit consent from individuals before using data for purposes other than the original intended purpose. However, this adds complexity to the use of personal data in large-scale smart city solutions, which demonstrators will have to contend with in the future.

CASE STUDY

PETRAS

As is the case with many emerging technologies, the Internet of Things is creating an unprecedented amount of data. This raises key privacy, trust and ethical issues, particularly when the data created is personal in nature. In the design of the IoT, these issues must be identified, resolved or mitigated, rather than left to be exposed at a later date.

In response to these challenges, the PETRAS Internet of Things Research Hub was launched in 2016. PETRAS is a consortium of nine leading UK universities, along with commercial partners, which will work together for three years to explore critical issues in privacy, ethics, trust, reliability, acceptability and security. [43]

Data Marketplaces: In order to facilitate the systematic exchange of data between members of the city ecosystem, a number of projects have sought to create city data marketplaces. These platforms are aimed at enabling data to be published, shared and purchased by all ecosystem members, including large established companies, small to medium-sized enterprises, start-up companies, as well as academia and the public sector. The most prominent example is the City Data Exchange in Copenhagen.

In these examples, while the technical platform worked well and contained all necessary transaction functionality and privacy controls, interviewees stated that they had underestimated the amount of advisory support required to create an active data exchange. An intermediary organisation was required to catalyse both the supply and demand sides of the market. Data buyers required support in expressing their specific data requirements and needed assurances regarding the longevity of data provision, while data suppliers required support in understanding which data was of value, appropriate pricing and suitable formats.

Some suppliers, particularly in the utility sector, were also reluctant to provide data to an open exchange due to fears it could be purchased by competitors and reveal sensitive information. Intermediary organisations have suggested that in future marketplace attempts, more attention should be paid to creating a structure which can impose some control on who is able to buy data, thus building trust and enabling a more automated exchange of data. They have also recommended using a use-case approach in order to entice both sides of the market into participating and to provide clarity around data requirements.

Several interviewees concluded that the industrialised data sale market is not yet sufficiently mature to support the creation of financially self-sustaining platforms.

Translating data into outcomes: In cases where local authorities or asset owners operated test beds, sensors and other data collection devices were often deployed in order to provide data to support service improvement efforts. However, many of these organisations had failed to appreciate the skills required to turn this raw data into actionable insights. Interviewees had different approaches to solving this issue:

- **A majority of test beds relied on local universities to provide the skills and services required.**
- **Some recommended procuring these devices as a service, rather than a product, from providers, thus ensuring that installation, calibration, data processing and maintenance was taken care of by a skilled party.**
- **Other test beds directly recruited appropriately skilled individuals into their teams (on a permanent or temporary basis) so that the one service team could work across a number of demonstration projects. This was seen to reduce costs compared to procuring multiple individual service packages.**

CASE STUDY

THAMES WATER INNOVATION AND SMART TECHNOLOGY NETWORK (TWIST)

TWIST has used a section of its water network to test a range of pressure sensors, acoustic loggers, smart meters and flow meters to detect leaks and visualise network energy usage. They enlisted the support of the University of Sheffield to develop tools, analytics and self-learning algorithms that allow them to turn data into actionable insights. However, TWIST found that the alarms generated were of limited use if not paired with response strategies and enough people to complete in-depth analysis. The fine-tuning between false positives and the number of alarms cannot be underestimated. They reported spending a significant amount of time cleaning the data to ensure it was of a sufficient quality and emphasised that innovators should not expect to have production-ready data available directly from collection. [44]

Creating communication infrastructures: Smart city solutions require digital communication connectivity on various levels, including fixed broadband, mobile broadband, machine-to-machine (M2M) and Internet of Things (IoT). Our research has uncovered several ways in which demonstrators have created the required connectivity infrastructures. [28] Interviewees were keen to point out that creating communication infrastructures does not always require significant capital outlay or an overhaul of existing infrastructure. There are existing solutions in the market which enable current infrastructure to be retrofitted with newer technologies. For example, street lighting infrastructure is often used to host a variety of sensors and camera equipment.

Taking the use of street lighting one step further, demonstrators such as Future City Glasgow have replaced some of their existing lighting infrastructure with ‘intelligent street lights’, which consist of:

- **A dynamic LED lighting network**
- **A central management system (CMS) to manage and control lighting levels**
- **A low-bandwidth wireless canopy to enable communication between the lights and the CMS**
- **A high-bandwidth Wi-Fi canopy to reduce dependency on the 4G network by mobile-based council services**
- **A living lab facility comprising a range of sensor deployments, including air quality, parking, footfall, noise, road temperature, water level and bin sensors**

Although the business case is driven by cost savings associated with transitioning to LED bulbs, the deployment of additional components has resulted in the creation of a distributed communications network across the city.

Other cities have used innovative financing arrangements to deliver the necessary infrastructure. Connexin and Cisco have partnered to deliver a large-scale smart city network in Hull that will support smart IoT applications as well as offering free Wi-Fi to users. By securing upfront funding from a Silicon Valley investment fund, and financing the offering through a comprehensive revenue-share model, it has been possible to remove the impact of city budget limitations and help increase the scale of digital infrastructure to support smart cities. [29]

Perhaps the most innovative method of delivering communications infrastructure was seen in Manchester, where the Digital Tameside project has utilised a cooperative model to aggregate previously disparate public-sector demand for connectivity.

CASE STUDY

DIGITAL TAMESIDE

The Digital Tameside project utilised a cooperative model to aggregate previously disparate public-sector demand for advanced connectivity. Tameside and its public-sector partners have invested in new connectivity infrastructure assets where a business case can be made to meet needs. This basic infrastructure is then leased to a cooperative alliance, comprising the local authority along with the various healthcare and education bodies, which in turn open it up for telecommunications companies to develop the delivery infrastructure and connectivity services. The smaller telecommunication companies jumped at the opportunity to build services on an affordable dark fibre network which costs them between one-fifth and one-eighth of the cost of developing the same services on the Openreach infrastructure. This has resulted in a broader range of connectivity services being made available for households and businesses. Using this innovative model and a pragmatic approach, Tameside Metropolitan Borough Council has enabled the rapid deployment of a new digital infrastructure that serves multiple sectors in the borough. Furthermore, at the end of the initial 10-year lease period, the infrastructure reverts back to public ownership, rather than transitioning to a commercial entity, ensuring that the public sector can continue benefitting from the asset in years to come. [45]

3.4 USER RESEARCH AND ENGAGEMENT

A major barrier to development and uptake of smart city demonstrators or solutions is the lack of engagement, understanding and trust of people who are the end users or are affected by these technologies. In the past, many smart city demonstrators have offered local citizens little chance to engage in the design and deployment of new technologies. While people tend to be the implied beneficiaries of the projects, they are rarely consulted about what they want, and their ability to contribute to making better solutions is often ignored. Demonstrators have an important role in introducing citizens to new solutions and providing valuable feedback to suppliers. [30]

CASE STUDY

SMART KALASATAMA

The Smart Kalasatama programme supported a start-up called Auntie who were developing a chat therapy service for those with worries and anxiety. While the business had a technical offering, they had never experienced servicing a real user. The living lab enabled Auntie to test several different service packages with a willing and diverse group of users to gain an understanding of the user experience and the effectiveness of different digital channels. Six months after using the living lab, Auntie had validated their service with real users and had developed an understanding of who would be able to procure the service. They have since gone on to secure commercial deals with several insurance companies in multiple countries. This highlights how access to and input from people is as important as access to infrastructure in smart city test beds.

Our research revealed a growing appreciation of the role that user research and engagement plays in the delivery and success of demonstration initiatives, with an increasing number of projects making attempts to become more open and participatory.

Various citizen-engagement methods were observed, including:

- **Co-design workshops:** the DALLAS programme placed considerable emphasis on the co-design of personalised healthcare and well-being tools and services, hosting a number of grass-roots community co-design workshops.
- **Public engagement days**: a number of projects held regular drop-in sessions to enable people to learn about the project and to contribute.
- **Creation of engagement clubs:** the Gateway CAV project in Greenwich invited citizens to become part of a POD club. Some basic training was provided to a statistically representative sample of individuals before taking part in the autonomous pod trials. The club proved extremely popular and was oversubscribed. UK Autodrive is now planning to use a similar approach in its real-world trials.
- **Use of crowdfunding platforms:** aiming to provide a bottom-up element to the demonstrator, the MK:Smart project utilised a crowdfunding platform to gather project ideas from the community. Over 100 ideas were received and 13 were funded and delivered.
- **Online forums:** several projects created online forums which enabled people to give anonymous feedback to projects taking place in their local area.

For some test beds, the expected users were not citizens but businesses. Our research discovered that test beds experienced difficulties in enabling small businesses to engage with emerging technologies that have long maturity horizons. These timescales are considerably longer than their typical planning horizons and often exceed their investment capacity.

A number of methods were used to attract SME users to test beds. These include:

- **Competitions:** understanding that SMEs may not have sufficient budgets to engage with a test bed of their own accord, a number of test beds were able to secure funding from economic development agencies or Catapult centres to run funding competitions.
- **Catapult networks:** it was also reported that the Catapult centres had extensive SME networks, and therefore test beds leveraged these networks to advertise their facilities.
- **Marketing:** as other test beds had sufficiently high profiles, only light marketing was required to attract business users.
- **Large businesses:** one of the most compelling methods of attracting small businesses was to use large businesses as an incentive. Large businesses would bring a challenge and some funding, thus attracting small businesses.

Several demonstrators experienced huge interest from the small business community; however, issues were identified in converting this demand into usage – for example, one test bed reported receiving up to eight enquiries a day from businesses, but over a period of 18 months, only 10 businesses actually used the test bed.

This further exemplifies the challenges involved in enabling SMEs to engage with emerging technologies. Test beds using low-TRL and prototype technologies are not plug-and-play environments – in the sense that a business cannot turn up and onboard themselves. Interviewees have had to provide a number of researchers and technical staff, not only to onboard innovators, but to support them throughout their demonstration.

CASE STUDY

5G TEST BED, BRIGHTON

Before being established, the partners behind the 5G Test Bed in Brighton commissioned some market research to understand who would use the test bed. As funding had been provided by the local enterprise partnership (LEP), they were keen to ensure there was an appetite from smaller businesses. The results showed that the following groups would be interested:

- Academics: in order to further their research,
- Corporates: in order to move ahead of their competition.
- A limited number of small businesses: The research showed that while the majority of SMEs do not want to engage in a low-TRL technology until its rollout, a minority will get involved earlier, especially if corporates are involved, as this builds confidence and may provide access to their supply chain. This minority contained businesses that had originated as university spin-outs and were therefore used to longer planning horizons, as well as deep technology businesses that were used to working with immature technologies.

Understanding that corporates hold the key to SME engagement, the test bed has designed a programme structure which places corporates as the creators of challenges and providers of funding, and SMEs as the innovators that propose and create solutions. The model is proving successful, as the SMEs are funded to participate and the corporates get the opportunity to shape innovative solutions to suit their own needs. The model also satisfies the LEP, as the small businesses have a clear customer in mind when developing solutions, ensuring that they meet a concrete market need.

LESSONS LEARNED

Resource Intensity: The biggest lesson learned in this subject area was that user recruitment and engagement, as well as SME onboarding, was considerably more resource intensive and costly than expected. However, it was unanimously agreed by interviewers that it was a necessary activity which saved costs in the long term due to the mitigation of re-design costs and user-acceptance risks.

Impact on timescales: While there were few objections to the value of human-centred co-design, some projects described an inherent tension between lengthy co-design processes and achieving delivery at pace and scale within project timelines. Recruitment of users took time, and they found it challenging to engage with products and services that were undergoing continuous iterative development. Constrained by budgets and delivery milestones, demonstrators typically achieved a balance between sufficient engagement and delivery.

Pre-emption of user groups: Smart city demonstrators often aim to create new services and/or delivery models. It is important to understand that the users, or user groups, for these new services may differ significantly from users of traditional services.

For example, there is currently a very homogeneous understanding of energy consumers due to the lack of differentiated offers in the market. Therefore, if a demonstration project is aiming to provide new energy services, such as maintaining a home at a certain temperature, or only providing energy from certain sources, there is very little understanding of what type of user may be interested in these services, and therefore little understanding of what the market size may be. The Smart Systems and Heat demonstrator has invested in an extensive research exercise to create new segmentations of energy consumers. This has allowed them to better understand the market and has informed who they have recruited to participate in the project.

Diversity of users engaged: Smart city technologies typically generate a lot of excitement, but it is critical that solutions are developed for all citizens and not just the engaged minority.

The AMS Institute in Amsterdam has made a concerted effort to engage different demographics of city users. For example, they have attached sensors and cameras to walking aids to gain a better understanding of how older people and the mobility impaired use the streets. This information will be used to inform projects in the future.

Similarly, the UK Autodrive project became aware that visually impaired people were concerned about their plans to operate an autonomous public transport system on the pavements of Milton Keynes. The project has since held co-design workshops with The Guide Dogs for the Blind Association to ensure their fears were considered and that the solution design would accommodate them as users. They are now helping the suppliers develop the vehicle interior to ensure they are dog friendly and accessible for the partially sighted.

CASE STUDY

SMART KALASATAMA, FINLAND

Smart Kalasatama is an innovation test bed and living lab in Helsinki which facilitates the co-creation of new urban services in a real environment with the users and people living in the area. There are currently 3,000 people living in the area, with 1,000 actively involved in the innovation projects taking place over the past three years.

The test bed has achieved this impressive citizen engagement through the creation of an 'Innovators' Club', which joins the city, large and small companies, property developers, planners and residents together to define what is needed and to test and evaluate services. Forum Virium, the city of Helsinki's innovation unit, acts as a coordinator organising frequent workshops and events across multiple themes and focus areas.

In addition to engaging citizens, small business engagement is another area of focus for the living lab. Agile piloting is a facilitated programme and involves funding made available for smaller demonstration projects. The aim of this activity is to accelerate new concepts into service prototypes and new business.

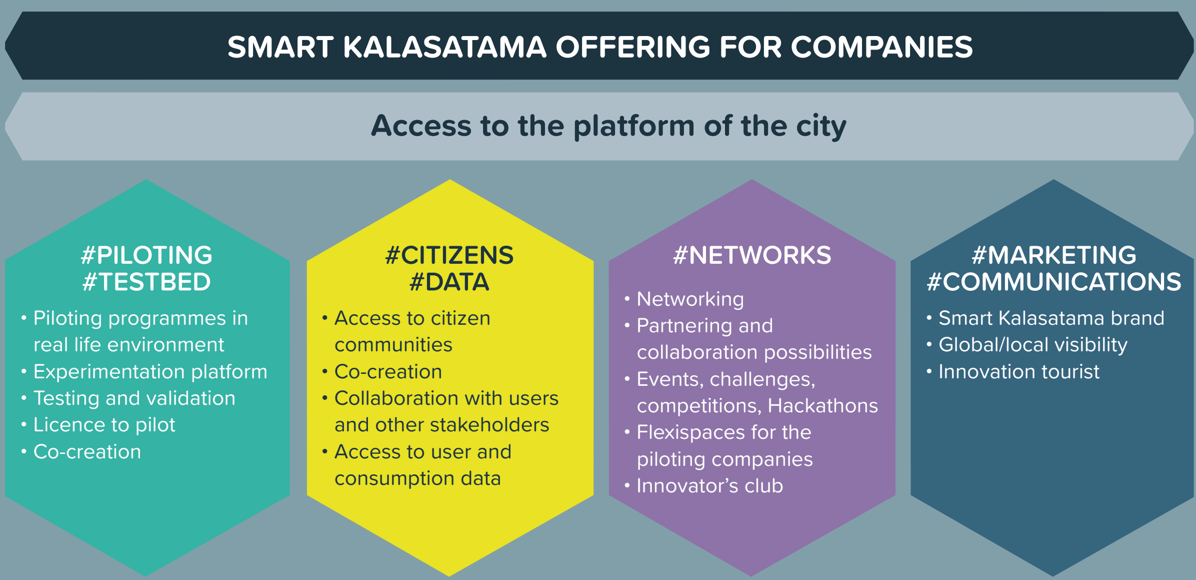


Figure 2: Smart Kalasatama Offering for Companies [46]

Recruitment: While some demonstrators were required to turn away willing participants due to the high volume of interest, others experienced difficulties in recruiting a representative sample of participants. This was particularly the case in health demonstrators, where participants were often required to have certain conditions or behaviours, and where data that would identify potential participants is restricted. For example, the Technology Integrated Health Management (TIHM) IoT Test Bed struggled to recruit enough patient–carer pairs for their remote care demonstrator due to an inability to identify and target participants, and due to conditions progressing during onboarding to a point where the patient was no longer eligible to take part. In these cases, the project recommended working closely with the wider ecosystem to identify potential participants, and the wider ecosystem involved working with GPs, social care providers and nursing homes.

Smart utility demonstrators also experienced challenges recruiting participants for demonstrators, often resorting to offering incentives such as vouchers or coupons.

Other projects have had considerable success when they have utilised existing community groups or where they have appointed a designated project partner to handle recruitment, user research and user testing. The CityVerve project in Manchester took this approach and appointed FutureEverything as their designated partner. FutureEverything were responsible for engaging local communities, introducing them to technologies and gathering feedback. While this required significant funds, the programme has spoken about how valuable this activity was to solution development and deployment.

CASE STUDY

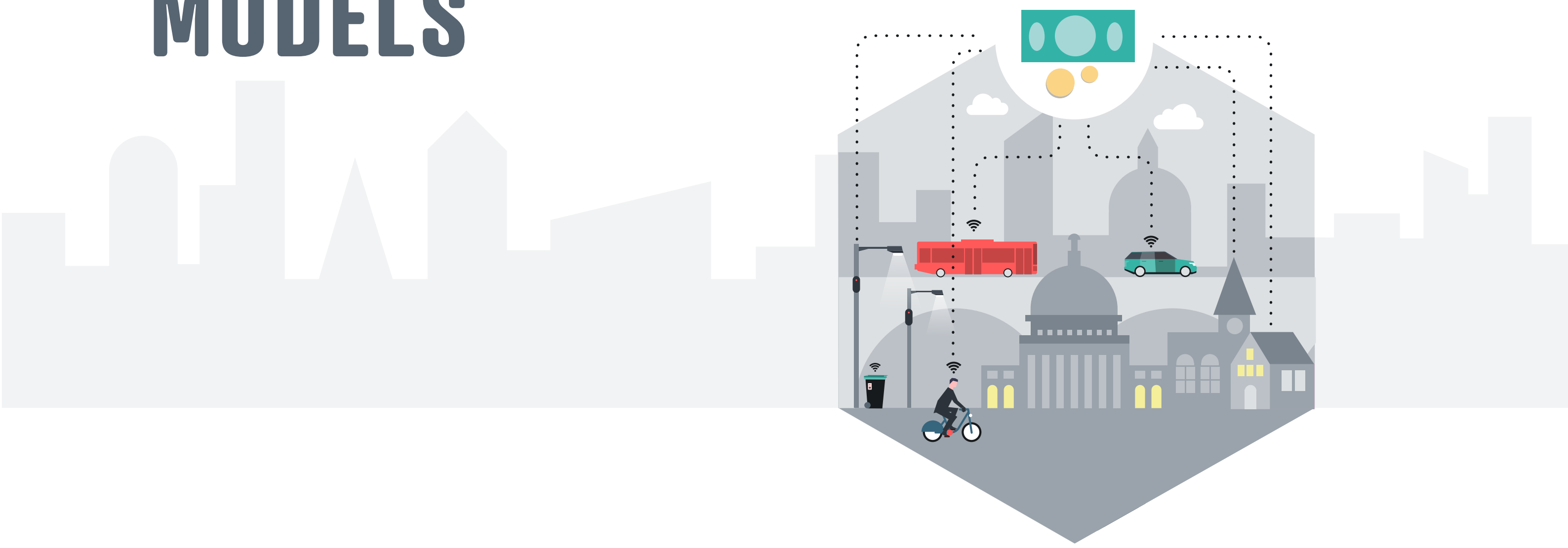
POWERMATCHING CITY, NETHERLANDS

The Powermatching City demonstrator took a different approach to participant recruitment due to the very early and revolutionary nature of the project. They asked local governments to provide information on active energy conservation groups and then engaged with each of them. Based on those engagements, the project chose the most suitable group and based the demonstrator in their locality. By targeting early-adopters, locating the demonstrator in their locality and implementing advanced but appropriate technical solutions and customer services, the partners were able to maintain an active and engaged cohort for the duration of their 10-year project!

FINANCE, GOVERNANCE AND INTELLECTUAL PROPERTY LESSONS LEARNED

The finance, governance and intellectual property (IP) arrangements surrounding smart city demonstrators are intrinsically linked, and they varied considerably based on funding sources, partners involved and use-case area. This section seeks to understand the range of finance, governance and IP arrangements used in large-scale demonstrators and the challenges experienced by those involved.

3.5 FUNDING, COSTING AND SUSTAINABILITY MODELS



While the value of innovation test beds and demonstration projects is widely appreciated and there is no shortage of willing participants, there remains a question regarding who has the motivation and resources to fund projects and create and build the required environments. By its nature, innovation comes with an associated risk of failure; however, these risks need to be taken in order to progress.

LESSONS LEARNED

Initial Funding Sources: Our analysis has shown that funds are received from a number of public- and private-sector sources.

Public-sector Sources: Public-sector funding was received from UK central government through departments and agencies such as the Department for Digital, Culture, Media and Sport (DCMS), the Department for Transport, the Department for Health, and Innovate UK. Underlying connectivity infrastructure has also been funded by central government through initiatives such as the Super-Connected Cities programme. Regional economic development agencies such as Scottish Enterprise also contributed to several Scottish demonstration projects.

Local enterprise partnerships (LEPs) were seen to be investing in open test bed environments which aim to catalyse local economic growth by providing small to medium-sized businesses with access to emerging technologies and support. Examples of such investments are:

- The 5G test bed at Westcott run by the Satellite Applications Catapult received funds from the Buckinghamshire Thames Valley LEP.
- The 5G test bed at Brighton run by the Wired Sussex and the Digital Catapult received funds from the Coast to Capital LEP.

At the European level, both the European Regional Development Fund (EDRF) and Horizon 2020 were cited as major sources of demonstrator funding. The latter was particularly praised for its ability to offer research and development, implementation and scale-up funding under one programme.

In the UK, sector-specific demonstration projects were funded by the following public institutions:

- **City services demonstrators:** funded by the DCMS, Innovate UK, ERDF, Horizon 2020 and the Higher Education Funding Council for England (HEFCE).
- Connected and autonomous vehicles demonstrators: funded by Highways England, the Department for Transport, and the Department for Business, Energy and Industrial Strategy (BEIS) through their Intelligent Mobility Fund administered by the Centre for Connected and Autonomous Vehicles (CCAV).
- **Health demonstrators:** funded by the NHS, the Department of Health, the National Institute for Health Research, Innovate UK and the Engineering and Physical Science Research Council (EPRSC).
- Last mile supply chain and logistics demonstrators: funded by Innovate UK and the Department for Transport through the Intelligent Mobility Fund administered by CCAV, Highways England and Transport for London.
- **Utility demonstrators:** showed the most variety in funding sources with money coming from ERDF, Horizon 2020, City Deals, BEIS and Ofgem's Low Carbon Networks Fund. Distribution network operators were also able to fund their own demonstration projects by leveraging Ofgem's Network Innovation Allowance (NIA) discussed in previous sections.

Those demonstrator environments that did not benefit from initial public-sector financial support spoke passionately of the struggles they experienced trying to generate their own income, while simultaneously trying to deliver meaningful projects and grow their capabilities. These demonstrators were strong advocates of secured baseline funding against a multi-year programme of activity, as this would have provided more certainty around outcomes.

Private-sector sources: In the majority of UK demonstration projects, public-sector funding was augmented by private-sector funding in the form of in-kind or material contributions. In rare cases, private-sector organisations provided contributions in the form of cash to demonstration environments to fund staff and activities during set-up, delivery and operation. This trend of public sector-led large-scale demonstration projects in the UK was consistent with the funding patterns of large international demonstrators, which were predominantly funded by central governments, national innovation agencies or the European Commission. As the scale of international demonstrators decreased, private-sector funding became more prominent, thus deviating from the UK trend.

Alternate funding models: One demonstrator was investigating non-capital market financial arrangements to fund the next phase of their project, taking inspiration from community wind energy projects in Germany and the use of municipal bonds to finance infrastructure in the USA. While this is not yet commonplace in the UK, our interviews revealed a strong appetite for further exploration of this avenue in the future.

CASE STUDY

COPENHAGEN SOLUTIONS LAB (CSL)

CSL requires that the city of Copenhagen funds local, innovative smart city demonstration projects. Previously, the Solutions Lab would fund projects only to find that the projects were treated as 'nice to have' initiatives and rarely became integrated into core city functions. By requiring payment, the Lab ensures that the proposed project is aligned to city needs, the required teams buy into the project and there is a solid business case.

The City of Copenhagen has been subjected to budget cuts in recent years. A proportion of the money saved through the cuts is placed into a fund which can be accessed by cities to pay for innovative solutions if they can demonstrate that the costs will be recovered in four to six years. This provides funding for the smart city demonstration projects and subsequent transactions.

CASE STUDY

EXETER CITY FUTURES, SUSTAINABLE FINANCE

In order to finance smart city demonstrators and solutions, Exeter City Futures has proposed the creation of a public sector-owned, commercially-operated, subsidy-free, sustainable finance solution such as a city development fund in partnership with the private sector as an option. The fund would provide a single gateway point of finance and delivery for the full spectrum of housing and infrastructure development in the city. The fund will have the skills, 'finance first' approach and critical mass required to deliver robust planning outcomes and the city's vision on place-making, and this will be at a pace and scale not possible via traditional public-sector delivery channels. The fund would be capitalised initially with the city council's asset base. Thereafter, the fund's flexible structure means that other institutions such as the NHS Trust, other local authorities or private-sector life companies can be added, thereby increasing the fund's impact.[47]

Balance of capital and revenue funding: A large number of demonstration projects and environments in the UK received large amounts of capital funding and little to no revenue funding. While capital funding is necessary to buy equipment, projects reiterated the need for revenue funding to administer the capital and secure resources to run the project. Despite struggling with this issue, several demonstrators were able to secure initial capital funding from one source and supplement this with smaller amounts of revenue funding from other public sources. Others were able to secure cash funding from the private sector to cover revenue costs.

Continuity of funding: Several demonstration projects highlighted the need for continued funding to support ongoing incremental change in leading locations. An example cited was that several regions were selected for the first round of demonstrator funding. However, in the subsequent funding rounds, a completely different set of locations were selected. It was felt that this led to multiple spots of mediocrity, rather than few locations of excellence, as capacity building had to be started from scratch each time. Naturally, there are valid arguments on both sides of this debate; however, there was a feeling that clustering of funding would result in better outcomes in the long term.

Costing approaches: Our analysis uncovered very few standardised costing methodologies for the components of innovative city-based demonstration projects. Strict grant agreements placed considerable pressure on those conducting initial costing activities to ensure their estimates are accurate.

Interviewees stated that the costing activity was challenging and unscientific due to the untested nature of many components. Labour costs were deemed particularly hard to estimate and led to the majority of additional costs incurred.

Demonstrators recommended using universities and R&D departments of large companies to cost innovative aspects of projects, due to their experience working with new and untested technologies. Large-scale infrastructure components should be costed using a survey approach; however, when this was not possible, projects commissioned experienced technology companies to conduct predictive costing exercises.

Sustainability approaches: In addition to the lack of standardised costing methodologies, there is also a lack of proven sustainability models for test bed environments. The majority of those interviewed had an underlying assumption of continued investment by state actors.

In some cases, asset owners had agreed to keep the deployed infrastructure operational for a set period of time – for example, Highways England has committed to keeping several real-world CAV test beds operational for two years following the initial project-funding period.

Of the few test beds that were already self-sustaining or were aiming for self-sustainability, securing continued corporate investment was seen to be the most viable option. Test beds have implemented several different models to secure this investment:

- **Partnership or sponsorship models:** a number of demonstrators were relying on corporate partnerships or sponsorships of the underlying infrastructure, research programmes, competitions or events to sustain operations. Examples of those using this model are Bristol is Open and MK:Smart. If this route is taken, test beds recommend developing a small number of meaningful long-term partnerships that will provide substantial, continued investments, rather than collecting a large number of smaller investments. Managing a large number of relationships is time consuming and the subsequent value captured by both parties is minimal.

- **Membership models:** several test beds were using membership models to fund ongoing operations. These ranged from large, multi-year memberships for corporates, to smaller, more flexible membership schemes for start-ups. Examples of those using membership models include the Power Networks Demonstration Centre and the 5G Test Bed Brighton. The 5G Test Bed is planning on implementing a ‘gym-style’ membership model for SMEs, whereby they pay a small sum of money each month and receive access to the test bed and the ability to use whatever equipment is available at the time of their visit.

- **Pay-per-use models:** a minority of demonstrator environments operated using a pay-per-use model; however, this was not popular due to the uncertainty of income. Where pay-per-use models were used, they were usually combined with other funding models in order to gain a balance between predictable revenue and flexible access.

It should also be noted that where membership or pay-per-use models were used, they were exclusively utilised by private-land demonstrators. Our research did not uncover any examples of membership models being used for real-world, public-domain demonstrator environments.

Interviewees stated that the reason for this was that they did not believe that an independent company could, or should, broker access to city assets on an open and repeatable basis. It was suggested that, with the right skills and capabilities, cities could provide this infrastructure-as-a-service facility themselves, in order to create a valuable revenue stream for themselves. Alternatively, an arm's length organisation could provide this service, as long as the city's best interests and challenges are kept at heart. Both of these options would open up ethical arguments regarding experimentation and consent from the wider population, which would need to be addressed.

From an innovator's point of view, there was a strong appreciation of the need for such test beds in order to test commercial viability of solutions, along with an expectation to pay for access to such a facility.

CASE STUDY

POWER NETWORKS DEMONSTRATION CENTRE (PNDC)

The PNDC has implemented a well-structured hybrid self-funding model to sustain its operations. This model comprises:

Memberships:

- **Tier 1 Memberships:** aimed at larger organisations (including network operators and technology companies) operating within the sector. Membership fees are used to fund a core collaborative work programme in which academics, researchers and industry representatives deliver a range of projects against strategic objectives. Tier 1 members receive royalty-free access to any co-developed intellectual property.
- **Tier 2 Memberships:** aimed typically at small to medium-sized enterprises (SMEs) who may have developed products or services for the utilities and wider energy sector. This level of membership has been most popular with overseas businesses wishing to localise their products to the UK context.
- Associate Memberships: aimed at start-up businesses that wish to have access to a state-of-the-art testing infrastructure but are unable to commit to sizable, multi-year membership fees. This also provides an opportunity for companies at this level to meet with potential end customers from within the industry.

Tier 1 and 2 memberships require a three-year commitment, which is critical from the perspectives of research programme delivery and relationship building. Due to the small size and limited resources of start-up organisations, associate members are only required to make a small one-year commitment.

Commercial projects: The demonstrator also operates an open-access policy which allows industrial organisations to fund stand-alone projects and enables academics to use grant funding to gain access.

Sponsorships: The PNDC has also secured contributions from regional economic development agencies and a Catapult centre to fund competitions to provide small to medium-sized businesses with access.

3.6 STATE AID

State aid is defined as "any advantage granted by public authorities through state resources on a selective basis to any organisations that could potentially distort competition and trade in the European Union". State aid rules can apply (among other things) to grants, loans and the use of state assets for free or at less than market price. These tools are often employed in smart city demonstration projects, and therefore participants must be acutely aware of the rules and whether they apply to them. [31]

Our research revealed that demonstrators experienced complex situations arising from state aid rules.

CASE STUDY

KEELE SMART ENERGY DEMONSTRATOR

The demonstrator is part funded by the ERDF and BEIS through the Stoke-on-Trent and Staffordshire Enterprise Partnership's City Deal. The principle outcome from the demonstrator and associated renewables is the saving of over 4,000 tonnes of carbon dioxide per annum.

In arriving at a fully funded project, the University has to pro-actively manage separate application processes, competing financial targets, differing financial years, and differing objectives and conditions relating to the use of the demonstrator.

LESSONS LEARNED

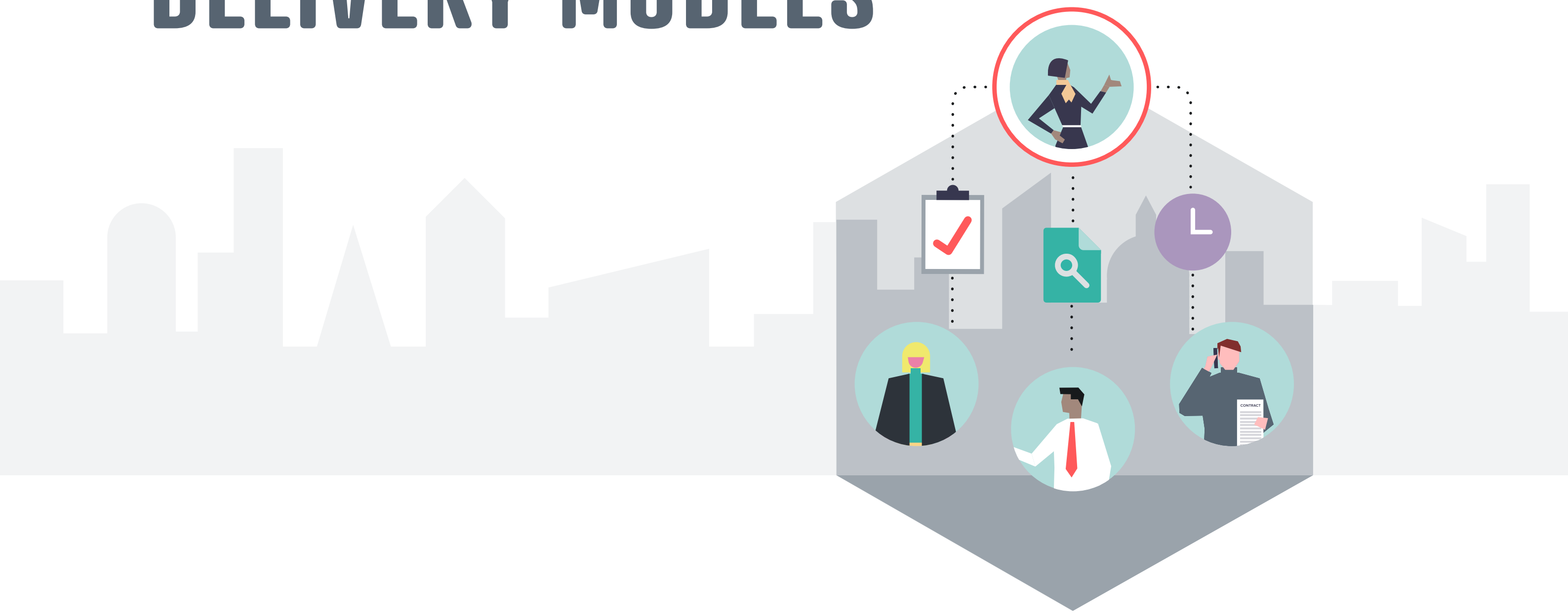
Seek professional advice: The overriding recommendation from interviewees was to seek professional advice on all matters involving state aid due to the complexity of rules and sheer number of situations.

Provision of public Wi-Fi: A number of demonstrators that delivered smart city connectivity infrastructures through the use of public-sector grants have experienced problems when considering using this infrastructure to provide public Wi-Fi. Due to the number of companies competing to deliver city-wide Wi-Fi services, the use of public funds in this way is said to distort the market. In the case of grant-funded connectivity infrastructure, the networks have had to remain closed to the general public and have been predominantly used for research purposes.

Distribution of public funding to others: Several demonstrators have sought to distribute public funding to small to medium-sized businesses through competitions and open calls in order to catalyse innovation. While giving small amounts of money to businesses is unlikely to distort the competition, this can present a state aid issue when small businesses are receiving funding from multiple sources. Total funding received sometimes exceeds the De Minimis Regulation, which allows aid of under €200,000 over a three-year period to be given to an undertaking for a wide range of purposes.[32] Demonstrators reported having to undertake due diligence on companies to ensure they were able to receive the proposed funding.

Future revenue generation: Concerns around the implications of state aid in relation to future revenue generation was primarily raised in reference to ERDF funding. Article 61 of the Commons Provision Regulation states that if a project will generate net revenue then the grant offered at the outset will be reduced by that figure. Alternatively, unforeseen net revenue could be clawed back at a later date.[33] This is impacting the sustainability of demonstrators funded through ERDF, as revenue generation was seen as a key aspect of continued finance, but without the full initial funding amount, many demonstrators would not be built in the first place.

3.7 GOVERNANCE AND DELIVERY MODELS



The governance and delivery of smart city demonstration projects and environments varied. While the models used for demonstration projects were relatively uniform, the models used for test bed environments were more varied.

Our analysis indicates that the governance models adopted were strongly influenced by the sources, structure and terms of funding received.

LESSONS LEARNED

Demonstration projects: Demonstration projects, particularly those funded by the European Commission and the UK government, utilised collaboration agreements to create delivery consortia comprising public, private and academic organisations. These arrangements typically involved the appointment of a lead beneficiary who would receive funding from the awarding body, and the creation of collaboration agreements or memoranda of understanding to set out the terms and details of requirements and responsibilities for other consortia members.

Test bed environments: Test bed environments were often seen to use special purpose vehicles (SPVs) to enable the participating organisations to achieve their joint objectives. Public-sector organisations stated that the use of SPVs allowed for swifter decision-making capabilities and shorter procurement timescales, while private-sector organisations believed that the use of SPVs offered a degree of protection from potential reputation risks. The vast majority of SPVs seen were not-for-profit in nature.

The most common forms of SPV used were:
- Joint ventures: have been used to create formal partnerships between universities, local government and other key stakeholders.
- Arm's length organisations
- Trusts and community-interest companies

The various participants in smart city projects and test beds reported challenges in learning to work under these new, multi-agency partnership models, citing cultural differences, resistance to change and little shared history of working together as key contributing factors. Despite these challenges, a number of projects and test beds have set up successful delivery vehicles.

CASE STUDY

BRISTOL IS OPEN (JOINT VENTURE)

In order to deliver and operate its network infrastructure, Bristol is Open was created as a joint venture company, owned by Bristol City Council and the University of Bristol. This allowed the infrastructure to be procured and deployed quickly. Furthermore, funds were received through multiple avenues and a joint venture allowed these funds to more effectively accounted for and managed. The joint venture then used a series of local host partnership agreements to deploy equipment in various locations across the city and charged variable rates to corporates, SMEs, academics and entrepreneurs based on usage.

Governance Arrangements: The majority of projects and test beds reported having several levels of day-to-day governance to ensure the successful delivery and operation of projects and test beds. Typical governance arrangements included:

- **Governing board:** comprising funders and key stakeholders. Responsible for providing financial, operational and strategic oversight.
- **Advisory group or steering group:** comprising prominent companies, research groups, regulators, government officials and independent individuals. These groups are responsible for providing expert advice and at times were seen to make additional financial contributions to the initiative.
- **Sub-committees and working groups:** comprising those directly involved in the project. Working groups were formed around particular workstreams or challenge areas to unblock issues and enable the project to progress.

CASE STUDY

SMART KALASATAMA (ARM'S LENGTH ORGANISATION)

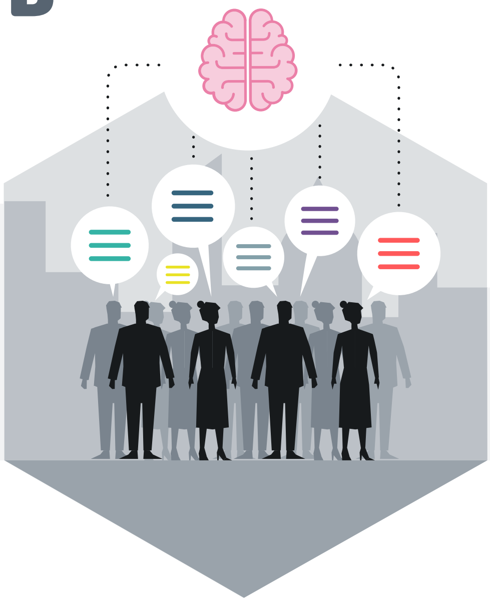
The Smart Kalasatama programme (2014–2017) is financed by EU regional funds and formally governed by the city of Helsinki. However, the programme is coordinated and delivered by Forum Virium Helsinki, a city-owned subsidiary (limited company) tasked with smart city innovation and development. As a subsidiary of the City of Helsinki, Forum Virium operates according to the city's legal and administrative processes and roles and responsibilities, which are defined in a cooperation agreement. While the city operates in departmental siloes, the arm's length organisation is tasked with working across them in order to enable cross-cutting innovation projects to progress more efficiently. [50]

CASE STUDY

MOBILITY OXFORD FOUNDATION (MOBOX) (COMMUNITY-INTEREST COMPANY)

The Mobility Oxford Foundation is aiming to create a living laboratory in Oxford to assess, validate and prove the business cases of a variety of innovative transport solutions. The MobOx Foundation has been set up as a community-interest company established by key stakeholders from the transportation industry and local stakeholders, including businesses, government and academic organisations in Oxfordshire. The group will be the custodians of any data produced and insights gathered from the laboratory. [49]

3.8 IP DEVELOPMENT, MANAGEMENT AND COLLABORATION



Our research revealed that the vast majority of demonstrators in the UK utilised a collaborative innovation approach to create new solutions. This method is said to deliver a number of advantages, including shortening of innovation timescales, sharing risks and reducing costs. Within these innovation consortia, protecting intellectual property and securing control over the future use of resultant solutions are the primary aims of many participants. Therefore, the agreement of collaboration terms and intellectual property rights were found to be the critical foundations of successful demonstrators.

Due to the importance of these agreements, interviewees reported spending huge amounts of time (on average between six and 12 months) negotiating terms prior to contract signature. This time and effort was often unaccounted for in project timescales and budgets.

LESSONS LEARNED

IP arrangements between partners in collaborative demonstration projects: Within collaborative demonstration projects, background IP arrangements were found to be standardised, with the party that brought the IP into the consortium retaining full ownership. However, foreground IP arrangements differed depending on the type of partners involved and the funding source. Two major arrangements were seen to distribute IP amongst partners:

- Firstly, resultant IP was split between partners on a work package or task basis. Under this arrangement, the partner that completed the majority of the work on a certain component retained full IP rights.
- Secondly, where a task or work package separation could not be achieved, the resultant IP was shared between several contributors.

Commercial partners such as corporates or small to medium-sized businesses were keen to obtain

IP rights, while local authorities and other asset owners were found to be less keen due to the high costs associated with maintaining IP and the lack of knowledge regarding how to commercialise. Asset-owning partners supported IP remaining with commercial partners, so they could develop market-ready solutions and sell to multiple customers. This would enable production of replicable solutions and would reduce the subsequent price, allowing both the solution owner and asset owner to benefit from economies of scale.

Universities were seen to have mixed views on IP ownership, with some requiring access to IP for research and teaching purposes only, and others keen to secure full ownership in order to develop their own commercial propositions or to license the innovation to other commercial actors.

Foreground IP arrangements became more complex and difficult to agree on as the number of partners involved increased. Collaboration agreements were found to be the most common way of formalising these arrangements between multiple partners. These agreements aim to enable the sharing of existing IP for collaboration purposes, protect partners from having their IP shared with external parties and outline the rights of partners over IP that will be developed. Projects unanimously reported that these agreements took considerably longer than expected to put in place, with legal negotiations typically lasting between six months and a year. The most common sticking points were intellectual property rights and liabilities.

Finally, where public-sector funding had been received, there was a requirement to make some IP open. This was normally achieved through the opening of data produced by the project and sharing of results in the form of published White Papers or through speaking at conferences. There were very few objections to this condition.

IP arrangements between innovators and open-access demonstration environments and test beds: IP arrangements within test bed environments were found to be more straightforward, with innovators retaining ownership of IP and the test bed operator rarely demanding any ownership of IP. However, test beds reported that they wished to encourage the sharing of knowledge and learning between innovation groups wherever possible. Some test beds used financial incentives to encourage knowledge sharing, offering cheaper access arrangements to those that agreed to share insights.

There were some instances where corporates and small businesses came together in open test beds to create solutions. Realising that small businesses are good at creating value but often struggle to effectively capture value, test bed operators sought to act as an intermediary and manage the unbalanced relationship between small and large businesses. The test bed operator provided support to small businesses around IP, advising them when to pursue full IP rights and when to prioritise other avenues to capture value, such as speed to market.

Structure of UK innovation projects: Several interviewees raised the point that the collaborative structure of many UK demonstrators facilitated innovation until a technology reached a certain point of technical readiness. The collaborative innovation approach was seen to work well for early-stage demonstrators where technologies and resultant solutions were still in development and were not ready for market. However, once solutions progressed past technology readiness level 6, commercial partners were less willing to work together as competitive instincts came into play. This was particularly prevalent in the CAV use-case area. It was suggested that the UK should investigate and promote other forms of innovation demonstrators for later-stage technologies in order to ensure that promising ideas reach the market.

DELIVERY CAPABILITIES AND SKILLS LESSONS LEARNED

In a basic sense, the delivery of city-based demonstrators requires access to city assets, the procurement of required products, goods and services and the creation of an appropriately skilled delivery team. Having already discussed the challenges faced in gaining access to assets, this section will provide a high-level overview of the skills and capabilities required to deliver smart city demonstrators, as well as outlining the challenges faced when procuring the necessary equipment and services.

3.9 DELIVERY CAPABILITY REQUIREMENTS

Our research briefly touched upon the skills and capabilities required to deliver large-scale demonstrators. Many of the findings were expected, with project management skills, relevant technical skills and legal and financial support all considered critical. However, our analysis also uncovered some lesser-known skills which were also considered necessary.

The following skill areas were considered critical to the delivery of demonstration projects and test beds:

- **Project and stakeholder management skills:** Strong project and programme management skills were deemed critical to the success of demonstration projects and test beds due to the large number of partners involved and the experimental nature of initiatives. However, demonstrators were keen to highlight that traditional project management methodologies are often based on client–supplier relationships. Innovation projects are often structured as collaborations or partnerships, which change the dynamics of the working relationship. Partners have limited leverage over one another, and therefore soft skills in building relationships and managing multiple stakeholders were seen as equally important as traditional project management training.

- **Technical skills:** The technical resources required varied significantly depending on the type and focus of the demonstrator; however, data scientists, IoT engineers, solution architects and business analysts were all found to be in high demand across the board. For demonstrators requiring significant consumer interaction, human factor experts were valued, while for virtual environments, GIS, BIM, CAD, CGI animators and game engine developers were deemed critical.

- **Financial and legal support:** Demonstrators typically receive funds from multiple sources, including the public sector, academic research funds and commercial partners. Each of these funding sources is subject to differing rules and regulations. Coupled with this, the range of partners and funding sources often creates complex ownership, liability and insurance positions. Therefore, interviewees recommended investing in specialist financial and legal skills to manage these complicated situations. It was felt this was particularly important when detailed with EU processes and requirements.

- **Marketing and communication skills:** While some demonstrators focused on technical demonstration, others focused on growing the market and enabling transactions. In these cases, demonstrators stressed the need to evolve from a team primarily consisting of technical resources to a marketing- and communications-focused team in order to effectively publicise the 'showroom' that has been created. They stated that the aim at this stage should be to get as many potential buyers to view the demonstrator as possible.

Demonstrators also emphasised that marketing and communication skills were also required to interact proactively with the press. Demonstrators that did not prioritise proactive press interaction suffered with sensationalised headlines that created fear amongst local citizens. Those that did prioritise press interaction benefitted from good coverage and publicity.

- **Change management skills:** A key aspect of demonstration projects is to change and improve the ways in which things are done. The existing processes, systems and solutions are often deeply embedded into an organisation's way of working, therefore requiring change management support to effectively land changes and ensure they are sustained across all members of the affected ecosystem.

- **Intermediaries and neutral coordinators:** Both test beds and demonstration projects highlighted the need for neutral parties to act as mediators and objective decision makers.

While very few demonstration projects had this role in place, a large number felt that if they were to undertake another project in the future, they would ensure someone was appointed to act as an independent intermediary. This recommendation was not intended to advocate the use of independent consultants; instead, it was intended to ensure someone always had the best interests of the demonstrator at heart, rather than the interests of individual partners. This person would be fair and objective and would take decisions to enable the most effective progression of the demonstrator as a whole, without prioritising the motives of any one partner.

Operators of test beds also stressed the need to put in place a neutral organisation to handle the coordination and facilitation of activities. Unlike demonstration projects, the majority of test bed environments had this role in place. The extensive use of special purpose vehicles allowed demonstrator companies to recruit their own staff that acted in the interest of the demonstrator, rather than innovators that came to use it. These neutral organisations conducted due diligence around proposed projects, brokered access to physical and digital assets and led engagement activities with the local community.

CASE STUDY

THE ROLE OF BENEFITS REALISATION

Benefits realisation can be defined as the process of identifying, defining, tracking, realising and optimising benefits throughout a change programme. The process ensures that benefits expected from vast sums of money spent on change initiatives are captured, and that they accrue to the appropriate party.[51]

As discussed previously, demonstration consortia often involve a wide range of different partners working together, including multinational corporates, micro-SMEs, academic institutions and local authorities. Why these organisations exist, what they hope to achieve and how they communicate vary considerably. While typically applied to internal large organisational change programmes, benefits realisation has an important role to play in innovation demonstration projects as the process can provide a framework through which the diverse consortia achieve their individual desired benefits while simultaneously working towards a common goal.

LESSONS LEARNED

Partner selection: Interviewees stated that initial partner selection was a strong indicator of success and that a mix of industry, academia and public-sector partners was ideal as each brings its own strengths. For example, in the smart city domain, councils understand the challenges faced by their citizens and the local environment, but they typically have limited budgets. In contrast, academic institutions can access funding, but they are increasingly being asked to apply their research to the real world and demonstrate impact. Several interviewees suggested that councils and, to a lesser extent, academia could use support in commercialisation, therefore illustrating how industrial partners play an important role in bringing business models and justification to the table.

Time taken to create an effective delivery consortium: Our interviews shed light on the challenges experienced by partners when trying to create effective delivery teams. In order to innovate, it is often necessary to bring together groups that may not have previously worked together. It takes patience and time to bridge the varying communication styles and to coordinate ways of working. Furthermore, it is also necessary to align and agree priorities both between partners and within individual delivery teams. For example, when creating a virtual demonstration environment, one demonstrator experienced tensions within their own delivery team, with some individuals wanting to prioritise user experience and others wanting to prioritise advancing the underlying technical functionality. With a limited budget, it took time and compromise to agree on a common way forward.

Continuity between project phases: Lack of continuity and communication between the proposal development, delivery and post-delivery teams was cited as a major cause of problems in the set-up and management of demonstrators. Insufficient clarity and availability of information was seen to impact speed of delivery and quality of outputs. Some projects reported a heavy reliance on independent consultants to deliver aspects of the project. This resulted in serious concerns about how knowledge was to be retained and disseminated once the project budget had expired. Interviewees recommended allocating a small ongoing budget to enable continued knowledge sharing.

3.10 PROCUREMENT

As discussed previously, the majority of smart city demonstration projects and environments in the UK involve public-sector authorities and often receive funding from the public sector. In line with this, they are therefore required to adhere to public-sector procurement regulations.

Public-sector procurement in the UK is governed by the EU Procurement Directives, which are then implemented into national legislation. Prior to the most recent directive (2014/24/EU), which was transposed into UK law through the Public Contracts Regulations 2015 (except in Scotland, which occurred through a separate regulation in 2016), four award procedures were provided:

- The open procedure, under which all those interested may respond to the advertisement by submitting a tender for the contract.
- The restricted procedure, under which a selection is made of those who respond to the advertisement, and only they are invited to submit a tender for the contract.
- The competitive dialogue procedure, under which a selection is made of those who respond to the advertisement, and the contracting authority enters into dialogue with potential bidders to develop one or more suitable solutions for its requirements – on which the chosen bidders will be invited to tender.
- The competitive dialogue procedure with negotiation, under which a selection is made of those who respond to the advertisement, and only they are invited to submit an initial tender for the contract. The contracting authority may then open negotiations with the tenderers to seek improved offers.

Procurement of the technologies and capabilities required to create cutting-edge demonstration environments under current regulations was reported to be a significant challenge. While some demonstrators made use of the competitive dialogue procedures to ensure received supplies were fit for purpose, others found this method challenging due to high transaction costs and a perceived ambiguity between transparency and fair competition.

CASE STUDY

KEELE SMART ENERGY DEMONSTRATOR

Keele University carried out the procurement process for the SEND works contract using the competitive procedure with negotiation (CPN). This procedure can be used by contracting authorities in a number of circumstances, including where the contract cannot be awarded without prior negotiation due to its nature, complexity, legal and financial make-up, and where the technical specifications cannot be established.

In accordance with the CPN process, the University carried out a selection-stage evaluation and invited short-listed candidates to submit an initial tender. The three highest scoring tenderers from the initial tender stage were then invited to participate in individual negotiation sessions with the University over a six-week period. The sessions allowed each tenderer to gain a greater understanding of the University's requirements so they could further develop their solution against these requirements. The sessions also provided a forum for the University and tenderers to raise key issues, identify areas requiring clarification and for tenderers to test requirements/proposals.

At the end of the negotiation sessions, all three tenderers submitted a final tender on which the University made the tender award. Whilst the CPN procedure incurred significant legal costs to ensure compliance and required a significant time and resource commitment from both the University and the tenderers, the process was successful, resulting in the appointment of Siemens as the main contractor for the SEND project. [52]

LESSONS LEARNED

Identification of suppliers: Identifying appropriate suppliers was deemed to be the biggest challenge faced by interviewees seeking to procure demonstrator products, goods and services. The challenge manifested itself in several ways:

- Firstly, demonstrators reported that the technological equipment required to create some demonstration environments was often still in the prototype phase and therefore was not easily located and procured. In these cases, it was felt there is a requirement to enter into detailed dialogue with vendors to understand what prototypes they have available and what functionality they can offer. There was a concern amongst interviewees that entering into this dialogue may breach procurement regulations. However, not entering into this dialogue heightened the risk of procuring technology that was not fit for purpose.

- Secondly, demonstrators reported that, due to the immaturity of solutions and lack of convergence in the market, they were unable to identify a supplier that could provide a complete solution. This required the use of multi-stage procurement processes to secure various parts of the overall solution, significantly lengthening the procurement timescales.
- Lastly, demonstrators reported having to ensure that suppliers understood the ambitions and scale of the environment they were building. For example, demonstrators reported going to market for advanced communication networks and finding they were being quoted extremely high prices for industrial quality equipment that would be better suited to running a national-scale network than for a small-area, experimental environment. Furthermore, demonstrators discussed the challenges they faced in securing

the appropriate level of support from suppliers, with some only wanting to sell products and others including costly support contracts alongside the equipment.

In the most recent update to the Public Contracts Regulations, a fifth award procedure has been added which may help solve some of the challenges discussed above.

The innovation partnership procedure aims to address the perception that the procurement regulations are inflexible and unsupportive of innovation by providing a more agile and flexible process. It enables procurement from R&D through to a proven solution, which can be with either single or multiple suppliers.

Under this procedure, a selection is made of those who respond to the advertisement, and the contracting authority uses a negotiated approach to invite suppliers to submit ideas to develop innovative works, supplies or services aimed at meeting a need for which there is no suitable existing ‘product’ on the market.

Essentially, innovation partnerships allow public authorities to launch a call for tender bids without pre-empting the solution, leaving room for suppliers to come up with an innovation in partnership with the authority. The procedure can be structured into successive stages of research and development and delivered without going out to further procurement for each stage of R&D prior to subsequent purchase. [34] Although there is limited experience of this to date, this could provide a new opportunity for SMEs to effectively compete with large organisations.

Furthermore, other changes to procurement regulations may also support the procurement of innovation test beds and environments. These include:

- Preliminary market consultations between contracting authorities and suppliers are encouraged to facilitate better specifications, better outcomes and shorter procurement times.
- More freedom to negotiate. Constraints on using the competitive procedure with negotiation have been relaxed, so that the procedure will generally be available for any requirements that go beyond ‘ off the shelf’ purchasing. [35]

IMPACT MEASUREMENT AND SCALING LESSONS LEARNED

While the ultimate aims and success criteria of demonstrators varied significantly, all had a common need to prove that these aims had been met and that the project had delivered expected impacts. Here, we explore the challenges and lessons learned around impact assessment. This section also explores the support of scaling and replication of demonstrators, including the use of knowledge-transfer mechanisms, the focus on ensuring interoperability of developed solutions and the involvement of regulators to secure favourable market conditions.

3.11 MEASURING IMPACT AND SUCCESS

Measuring the impact of demonstration projects and test beds is critical for proving value, evidencing business cases and ultimately creating new markets. Our analysis found that for the majority of demonstrators, impact measurement activities were conducted by universities, as they had experience of assessing the impact of new and innovative ideas.

In line with the differing aims and objectives of test beds and projects discussed earlier in this report, definitions of success varied significantly, as did the desired impacts. The following success and impact areas were identified as important to consider and measure:

- **Economic, social and environmental impacts:** The vast majority of interviewees stated that in addition to measuring the economic impact and return on investment (ROI) of a project, it was also critical to consider the social and environmental impacts of demonstrated solutions. They also reiterated the importance of mapping impact to the relevant stakeholders to ensure sufficient bankable benefits accrue to a stakeholder that has the ability to procure the solution. There were numerous examples of projects which had developed solutions that delivered large but widely distributed benefits. No single stakeholder was able to procure these solutions and agreements between multiple stakeholders are extremely difficult to reach.
- **User impacts:** It was felt that too much focus was often placed on the economic impacts of solutions, while very little attention was given to how the users felt while using the solutions. The business cases of many smart city solutions rely on usage by consumers, and therefore it is imperative to evidence that the solution is something that consumers want and need. Projects recommended that in addition to more formal, quantitative methods of evaluation, they

should also invest in collecting qualitative feedback from consumers using focus groups and interviews.

- **Education impacts:** Other test beds and demonstration projects had a strong focus on education – for example, the MK:Smart project created a massive online open course (MOOC) to support the community in understanding sustainability issues. This course was subsequently completed by over 40,000 students, which was considered an important positive impact for the programme. Furthermore, MK:Smart also worked extensively with local schools, educating children about sustainability and the use of data science.
- **Evidence of transactions and market growth impacts:** Some test beds, such as the Grow Smarter project, aim to act as a showroom, demonstrating solutions to potential buyers. These demonstrators measured impact in terms of the number of visitors to the test bed, new connections formed between the supply and demand sides of the market and the number of additional deals completed.
- **Policy impact:** Other demonstrators measured impact in terms of the number of recommendations that were taken up by policymakers.
- **Technical success:** In earlier stage (lower TRL) demonstration projects, assessing whether solutions functioned technically and using this information to further optimise performance was often deemed more important than measuring the impact it had delivered.
- **Interoperability success:** Interviewees stated that it was becoming increasingly important to ensure that solutions developed during projects worked with existing systems and those being developed by other innovators.

LESSONS LEARNED

Despite good progress, a number of challenges remain that inhibit measurement of the impact of innovative demonstration projects and test beds:

Evaluation stifling innovation: Our interviews revealed concerns among demonstrators that a disproportionate focus on evaluation and assessment, particularly at an early stage, stifles innovation and leads to the premature closure of demonstration projects and test beds. Standard evaluation frameworks used for large-scale infrastructure projects were deemed not fit for purpose to assess impact and success for experimental and iterative innovation projects. It was deemed to be critical that assessment efforts were appropriate and proportional to the maturity of the solutions being tested and that failure should be tolerated (to an extent) in order to progress. There was an agreement among interviewees that assessments should take into account all types of impact, rather than purely economic. The need to ensure value for money was understood by all interviewees.

CASE STUDY

FUTURE CITIES CATAPULT

The Future Cities Catapult has developed the Performance in Use (PIU) toolkit as a practice guide for conducting impact assessment for urban innovation projects. Building on existing impact assessment frameworks such as the HM Treasury's Green Book, it provides a step-by-step model for practitioners to analyse and integrate economic, environmental and social impacts. Its aim is to help users prospectively appraise potential impacts of planned interventions and retrospectively evaluate the actual impact and effectiveness of deployed solutions using an open and flexible framework.

Moving goalposts: Robust impact measurement requires historical data to establish baselines before the project commences. However, the nature of many innovation projects means that they are exploratory and that scope and aims may change as the project progresses. This creates issues when looking to compare resultant impacts to the original baseline data, as activities have often deviated from initial plans. The A2M2 project has used a logic model approach to inextricably link inputs, activities, outputs and impacts. Using this model, while the exact tasks or activities completed may change, the inputs and impacts should remain consistent.

Measurement of long-term impacts: Projects were able to measure short-term efficiencies and impacts, which is crucial to enable initial procurement. However, it is often the long-term impacts which deliver the most substantial benefits. Interviewees experienced challenges in measuring, evidencing and attributing long-term impacts, such as improved health outcomes, within the short timescales of demonstration projects. The DALLAS project recommended using an 'immediate, next and future model' to categorise impacts. The 'immediate' impacts can be strongly evidenced and should enable immediate procurement, the 'next' impacts can be reasonably evidenced and can provide rationale for investment over two to five years, and finally, the 'future' impacts can be more speculative and ambitious as the underlying business case has already been proven.

Measurement of unintended impacts: While most impact assessments solely focused on measuring the intended benefits, interviewees stated is was equally important to consider the unintended consequences of projects. For example, the Plugged-in Places project installed electric vehicle charging infrastructure across the north-east region of the UK. While there were many positive impacts of this activity for consumers, the project was also required to consider the impacts on other groups such as mechanics and emergency services. This allowed the project to identify skills shortages in the car-repair sector and changes required in the processes of the emergency services when responding to accidents involving electric vehicles. Without considering these unintended consequences, the future viability of the project could have been jeopardised.

3.12 SCALING TO NEW MARKETS

It is critical for companies to be able to develop and test products and services which can scale to a larger market. A report by Willem van Winden identifies three approaches that can be used to scale smart city solutions. These are:

SCALING TYPE	DESCRIPTION	MANIFESTATION	EXAMPLES
Rollout	Bringing a smart city solution to the consumer or business-to-business market, or applying the solution across the entire organisation	Market rollout, Organisational rollout	Smart energy meters introduced in the consumer market or the creation of a city data marketplace
Expansion	Adding more partners, users or functionalities to a smart city solution, or enlarging the geographical area in which the solution is applied	Quantitative expansion Functional expansion Geographic expansion	Enlarging the area of a smart lighting solution
Replication	Replicating (exactly or by proxy) the solution in another context by the original partners involved in the pilot project, or by others	Organisational replication Geographic replication	Replicating a tested last mile logistics solution in a new city

LESSONS LEARNED

A number of factors were seen to impact and enable the ability of smart city demonstration projects to scale.

Management of the transition to full operation: Successful scaling of smart city solutions requires the skilful management of the transition from demonstration project to operational solution. The skills required during the explorative innovation phase of a demonstration project differ significantly to the skills required to operationalise a large-scale deployment. This must be planned for and organisations should ensure a connection remains between the innovation demonstration team and the business-as-usual team.

The projects that were most successful in handling the transition from demonstration to commercial operation used a phased approach to project delivery. Early project phases typically focused on technical proofs of concept, while middle phases focused on technology optimisation, the development of new services and the implications for the existing market. The final phases focused on future market development, including developing supporting services and skills in the marketplace in order to enable the operational deployment of the solution. Projects that utilised this method of scaling typically ran for six to 10 years, highlighting the need for continued funding and commitment from project partners. Each phase of the project requires a different mix of skills and capabilities; however, due to the continuous nature of the project, knowledge and learning is retained and utilised in the next phase.

A common finding in those projects that failed to transition was that the demonstrator delivery team had been disbanded once initial funding had expired, and therefore all tacit knowledge had been lost.

Knowledge transfer mechanisms: Effective knowledge transfer between organisations is often necessary for scaling to occur, particularly for replication scaling. In the smart city domain, many large businesses such as Cisco have developed global programmes which help centralise insights from multiple projects. However, many projects are run by local authorities or smaller businesses that are not able to benefit from international networks. In these cases, knowledge transfer is more difficult, but several approaches have been identified from our research:

- **Partnerships:** a number of demonstrators have developed partnerships with other cities. For example, having successfully delivered a smart street lighting demonstration, the city of Glasgow is working with three other Scottish cities to expand and replicate this smart infrastructure. The city has held workshops with other lighting teams and has shared its requirements specifications to accelerate learning and procurement activities.

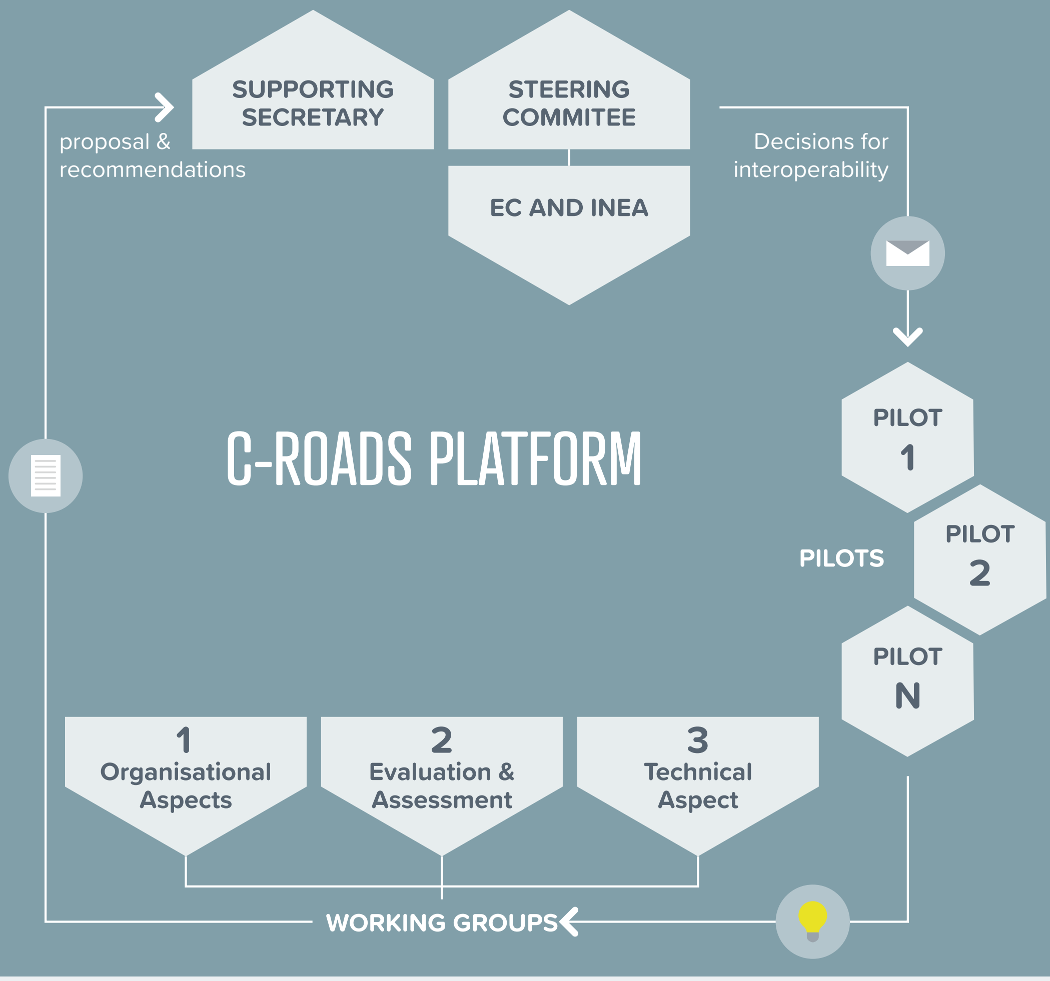
- **Follower cities:** It is becoming commonplace to structure European Commission-funded smart city projects in such a way that a small number of cities are funded to implement solutions while a larger number of cities are funded to participate in knowledge-transfer activities. For example, the Grow Smarter project has three ‘lighthouse’ cities who lead the implementation of solutions and host knowledge transfer visits for five ‘follower’ cities. These follower cities closely follow the lighthouse cities to learn from their experiences, identify measures that are suitable for their specific local context and develop a replication plan tailored to their local needs. To facilitate further knowledge transfer, the Grow Smarter project is currently looking to recruit 20 additional cities to form a city interest group. These cities will receive detailed information on solution implementation and have the opportunity to receive free capacity-building workshops.

- **Umbrella programmes:** Where many projects around a certain use-case or technology have been funded, it is increasingly common to see the formation of 'umbrella' programmes. These overarching programmes sit above the individual demonstration projects to harmonise findings and deliver best practice and specifications.
- **Memberships of associations and industry groups:** were seen as key ways to exchange knowledge, particularly in the utilities sector. However, several interviewees reported being overwhelmed by the number of active industry forums and described not knowing which ones to engage in and where to prioritise their time.

CASE STUDY

C-ROADS PLATFORM

The C-Roads platform has been created by the European Commission to harmonise the deployment activities of cooperative intelligent transport systems (C-ITS) across Europe. The platform captures information from each member country's pilot projects, harmonises input and pushes out standards and specifications to ensure knowledge is shared and common solutions are developed. (53) The aim is that eventually these standards become accepted as de-facto international standards by bodies such as ETSI and ISO. This model appears to be working well; however, the speed at which the platform conducts harmonisation activities is critical to avoid delaying project progress.



These demonstrators typically identified a number of individuals to become trusted advisors and tasked them with distilling and relaying pertinent information to the demonstrator.

- **Creation of standardised frameworks:** Some demonstrator projects have taken a different approach to knowledge transfer. Rather than directly engaging potential implementers, they have created detailed and open implementation documents.

CASE STUDY

POWERMATCHING CITY

The Powermatching City project, along with a number of other collaborators, has led to the development of a Universal Smart Energy Framework (USEF) which aims to become the international standard for smart energy systems. The framework details the market model for the trading and commoditisation of energy flexibility, along with the architecture, tools and rules, to make it work effectively. Fully implemented, the USEF delivers all stakeholder interaction process models, communication protocols and coding examples to accelerate software development. Its open ICT architecture provides the freedom to create unique and commercially competitive smart energy products and services while delivering a common standard on which to build them. Ultimately, this framework should accelerate future implementations and ensure that solutions are rapidly scalable. To date, two further demonstrator projects in the Netherlands have implemented the USEF. [54]

Data and systems interoperability: Many smart city projects rely on data exchange between organisations and interoperability of IT systems. However, fragmented ownership landscapes, legacy IT systems and a lack of widely accepted technical standards is hindering the scaling of smart city solutions. Furthermore, there is limited incentive for existing vendors to make their solutions interoperable as this would release locked-in customers and result in loss of market share. Nowhere has this been experienced more acutely than in the healthcare sector.

For example, the Delivering Assisted Living Lifestyles at Scale (DALLAS) healthcare demonstrator was a programme comprising four individual programmes tasked with exploring the use of innovative products, systems and services to support people in living healthy, active and independent lives. Interoperability is needed to facilitate data and information sharing in alignment with more integrated, personalised healthcare.

While the grant agreement expected the four consortia to communicate, it did not stipulate that they should develop interoperable solutions with common outputs to enable scaling in the future.

The healthcare landscape in the UK is extremely fragmented, and while the programme recognised this, it did not put in place a formal process to bring it together. The grant agreement did not clearly stipulate that each of the four consortia should develop interoperable solutions with common outputs. Therefore, the consortia each developed their own solutions but created an open application programming interface (API) to enable interoperability. As each consortium developed a different API, unique connectors had to be designed, built and maintained to enable interoperability. This model was not sustainable, and therefore the system could not achieve interoperability or scale. What should have been developed was a common API which would have allowed for replication of the systems to multiple sites.

Several years later, Innovate UK launched their £8.4m Internet of Things Ecosystem competition, which funded eight individual projects. [37] This time, the grant agreement explicitly stated that the projects must work together to deliver interoperable solutions. The resultant interoperability specification became Hypercat, which has since been applied to multi-million-pound smart city projects, attracted more than 1,000 industry members, gained support in 47 countries and become an international standard for interoperability. [38]

CASE STUDY

DIGITAL HEALTH AND CARE ALLIANCE (DHACA)

Originally one of the four DALLAS consortia, DHACA is now an independent free-to-join membership-led body of statutory and private-sector service providers, manufacturers, software developers, consumer representative bodies, regulatory bodies and trade bodies who want to create an opportunity to develop large-scale collaborative business models through the promotion of open standards, collaborative architectures and interoperability. It does this through the following programme of activities:

- Supporting demand-side approaches to digital health and care by collating and recommending common requirements specifications for procurement purposes.
- Shaping industry's approach to interoperability in the assisted living market and supporting the move towards large-scale business models.
- Creating a DHACA 'kitemark' to signify interoperability and to grow market awareness.
- Providing DHACA members with knowledge, support and partnership opportunities to exploit fully the opportunities arising in this dynamic and growing market. [55]

Regulatory, legal and policy frameworks: Regulatory, legal and policy frameworks play a pivotal role in the scaling processes of smart city projects. Many demonstration projects fail to scale because they are shielded from real-world regulation and market forces.

Various levels of engagement with regulators were required across the demonstrators interviewed. The amount of engagement was typically dependent on the maturity of the technology, scale of implementation and whether consumers were directly affected. Engagement approaches ranged from informal discussions, to regular roundtable events, to allocating regulators a seat on advisory boards. Projects highlighted that engagement of regulators is an important activity, but was not always costed for during planning. They recommended accounting for this in the future.

In general, UK regulators have been welcoming of smart city projects and have been engaged throughout the set-up, delivery and operation of demonstrators. Some regulators were found to be particularly proactive in the enablement of demonstration projects. For example:

- The Department of Transport has created its Code of Practice for Testing of Automated Vehicle Technologies, which provides guidance around safety and risk to anyone wishing to conduct testing of CCAV technologies on public roads. [39]

- Ofgem launched its Innovation Link, a 'one-stop shop' that offers support on energy regulation to businesses looking to introduce innovative or significantly different propositions to the energy sector. [40]

While research showed that regulators were open to granting regulatory concessions for small, low-impact, temporary demonstration projects, securing large-scale concessions or permanent regulatory change was a different matter. Projects felt that pushing for sustained regulatory change was beyond the scope of their activities and expected commercial partners to continue the push for change based on the requirements of their solution. From a regulator perspective, those interviewed reported no immediate plans to change regulation in response to smart city demonstration projects, wishing to allow markets to mature as organically and openly as possible before implementing rules and regulations.

Despite this, there was a growing appreciation of the need for larger regulation-adjusted demonstration areas in order to prove the commercial viability of solutions rather than just technical feasibility.

CASE STUDY

ENERGY INNOVATION ZONES

The concept of energy innovation zones (EIZs) has been developed in the West Midlands to provide the missing link within the UK innovation ecosystem for energy. The zones would provide opportunities to deploy energy innovations commercially and as part of an integrated system at a scale to which customers can relate. This will provide the critical link between pilot demonstration and global market success. The model will be piloted in at least four high-profile locations across the region and subsequently rolled out nationally.[56]

Work with partners who can provide a pipeline of expansion and commercial opportunities: A final method of scaling utilised by demonstrators was to partner with organisations that have the potential to provide a pipeline of future opportunities. Under this model, larger companies have acted as the challenge owner and smaller companies have created and demonstrated innovative solutions, incentivised by the potential market presented by the larger company and similar organisations. While the larger company is rarely contractually obliged to purchase the resultant solution, it provides a real market incentive for innovators and ensures that demonstrators aim to meet an identified challenge, rather than simply demonstrate technology.

CASE STUDY

AMSTERDAM INSTITUTE FOR ADVANCED METROPOLITAN SOLUTIONS

AMS Institute participates in a project with a hotel chain to measure the use of energy consumption of guests and to monitor the usage of hotel-owned bicycles. The resultant data provide insights into water and energy usage and can be used to create awareness, improve customer experience and reduce costs. While at this stage the project is focused on one hotel, there is the potential to scale this intervention across other hotels in the chain.

This method has also been utilised by various central governments. In 2017, the UK government launched its Industrial Strategy Challenge Fund to strengthen science and business innovation. In relation to the Transforming Construction challenge, the Department of Education has highlighted its pipeline of new school building projects.[41] This move provides confidence to the market that if they develop useful solutions, there is a pipeline of projects on which to implement them. This move should support the scaling of demonstrated innovations.

4

RECOMMENDATIONS

Interviews conducted with demonstrator representatives and industry experts have unveiled the challenges, lessons learned and best practices that have emerged during the planning, delivery and operation of demonstration projects and test bed environments. The findings have led us to compile the following list of recommendations for future demonstrators:

Engagement and access

- Involve relevant asset owners as early as possible during the planning phase to secure buy-in, gain access to assets and enable the smooth deployment of equipment.

- Invest in user research and user recruitment to ensure solutions address the needs of citizens and to provide innovators with an engaged cohort of users with which they can test their solutions.

Finance and governance

- Consider ongoing funding and financing options at the outset and build towards a sustainable operation rather than relying on additional grant funding. Similarly, demonstrations projects should plan their legacy to facilitate continuity between themselves and future demonstrator initiatives.

- Create advisory boards comprising relevant stakeholders from the wider ecosystem (such as regulators, policy officials, etc.) to ensure that demonstrators are exposed to current and anticipated market conditions.

Delivery capabilities and skills

- Invest in benefits realisation and change management capabilities to ensure that all stakeholder aims and expectations are aligned, and that the required changes across the affected ecosystem are implemented, accepted and sustained.

- Staff test bed environments with the relevant practitioners to enable non-expert users to make use of the facilities.

Success measurement and scaling

- Put in place appropriate knowledge-transfer mechanisms to facilitate the scaling of solutions within a city and the replication of demonstrated solutions across locations.

- Work with partners that can provide a pipeline of commercial opportunities beyond the demonstrator period.

This report aims to provide a view of the smart city demonstrator landscape, as well as help future demonstration projects and test beds understand the challenges others have faced, lessons they have learned and approaches they have used to move forward. These findings should equip those involved in this space with the knowledge they need to more effectively plan, deliver and operate smart city demonstrators.

Naturally, building this knowledge base is an ongoing endeavour. For that reason, Future Cities Catapult has been undertaking research in a variety of related areas, from impact assessment to the creation and implementation of smart city strategies. Please visit our website to see other reports on these topics.

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APPENDIX A: CONTRIBUTORS

We would like to extend a special thanks to all those who generously contributed their knowledge, ideas, feedback and time to this work:

INTERVIEWEE NAME	INTERVIEWEE ROLE	ASSOCIATED PROJECT
Stuart Revell	Managing Director, RTACS Ltd	Delivering Assisted Living Lifestyles At Scale (DALLAS)
Kevin McGeough	Director, Ebbsfleet Garden City Healthy New Town	NHS Healthy New Town: Ebbsfleet
Mark Kenny	Transformation Lead, Surrey and Borders Partnership NHS Foundation Trust	Technology Integrated Health Management (TIHM) IoT Test Bed
John Eaglesham	Founding Director, Digital Health and Care Alliance	Digital Health and Care Alliance (DHACA)
Yannis Georgas	Project Manager, Cisco	City Verve
Adrian Slatcher	Senior Policy Officer, Manchester City Council	City Verve
Jonathan Brown	Programme Manager, ERDF Strategic Interventions	Future City Glasgow
Graeme Scott	Principal – Intelligence / Deputy Regional Director, IBI Group	Future City Glasgow
Enrico Motta	MK:Smart Project Director	MK:Smart
Glenn Woodcock	CEO and Founder, Exeter City Futures	Exeter City Futures
Liz O'Driscoll	Head of Innovation, Exeter City Futures	Exeter City Futures
Claire Lewis	Senior Business Development Manager, Visteon	UK CITE
Tim Armitage	Associate Director, Arup	UK Autodrive
Gary Crockford	A2M2 Project Coordinator	A2M2 Corridor
Martin Pett	Principal Technologist, Transport Systems Catapult	Transport Systems Catapult Visualisation Lab
Nick Clay	Head of Homologation and Quality, Arrival GB	Robopilot
Frances Fernandes	Director, Fernhay	Low Impact City Logistics
Robin Haycock	Ideas to Results Director, Fernhay	Low Impact City Logistics
John Beaumont	Chief Digital Officer, Thames Water	TWIST
Catalina Pedraza	Specialist Project Manager, Thames Water	TWIST
Ian Madley	Head of Partnership Development, Keele University	Keele Smart Energy Demonstrator

INTERVIEWEE NAME	INTERVIEWEE ROLE	ASSOCIATED PROJECT
Tim Stiven	Head of Delivery, Energy Systems Catapult	Smart Systems and Heat Demonstrator Phase 2
Steven Whyte	Business Development Manager, Power Networks Demonstration Centre	Power Networks Demonstration Centre
David Rutherford	Chief Executive, Power Networks Demonstration Centre	Power Networks Demonstration Centre
Emma Shorman	Partnership Funding Development Specialist, Science Central	Science Central
Yvonne Huebner	Strategic Projects Manager	Science Central
Colin Herron	Managing Director, Zero Carbon Futures	Plugged-in Places
Paul Wilson	Chief Marketing Officer, TM Forum	Bristol is Open
Phil Jones	Managing Director, Wired Sussex	5G Test Bed Brighton
Tim Rainey	Assistant Chief Executive, Tameside Council	Digital Tameside
Ashweeni Beeharee	Head of Communication and Systems Engineering, Satellite Applications Catapult	5G Terrestrial & Satellite Network Infrastructure Test Bed and Mobility Oxford (MobOx)
Martine Harvey	Senior Technologist, Transport Systems Catapult	ITS Demonstrators
Alisdair Ritchie	Impact Champion, PETRAS National IoT Research Hub	PETRAS Internet of Things Research Hub
Limin Hee	Director of Research, Centre for Liveable Cities	Centre for Liveable Cities
Veera Mustonen	Programme Director, Smart Kalasatama, Forum Virium Helsinki	Smart Kalasatama
Bill Howe	eScience Institute, University of Washington, USA	Seattle Smart City
Marius Sylvestersen	Programme Manager, Copenhagen Solutions Lab, Denmark	Copenhagen Solutions Lab
Kees Slingerland	Director, AMS Institute, Amsterdam	Amsterdam Institute for Advanced Metropolitan Solutions
Irin Bouwman	Consultant Market and Policy Development DNV GL – Energy	Powermatching City
Gustaf Landahl	Grow Smarter Project Coordinator	Grow Smarter
Renny Ulka	Service Manager, City Data Exchange, Hitachi Consulting	City Data Exchange

AUTHOR'S NOTE

The public and private sectors are continuing to fund smart city demonstrators and pilots at pace. As the sums of money involved increase, so do expectations around outcomes and impacts. While high-level impact assessments are occasionally funded at the end of projects, rarely do these evaluations look at the discrete challenges that have been faced by demonstrators when seeking to achieve their objectives. Even more rarely do these evaluations provide a critical examination of the reasons for underachievement or failure.

It is for this reason the Future Cities Catapult has written this report. By interviewing over 40 demonstrators and industry experts, we have aimed to uncover the distinct challenges faced by demonstrators and have highlighted the innovative ways these challenges have been overcome. Appreciating that smart city demonstrators vary significantly in terms of their size, location and goals, we have also sought to provide an overview of the demonstrator landscape, with an aim of understanding whether the right mix of demonstrators exists to successfully accelerate solutions through the maturity curve, and ultimately solve complex city challenges.

We hope that this report will support future demonstrators set themselves up for success and avoid the mistakes of those before them. Furthermore, by highlighting challenges that remain unsolved, we hope that appropriate resources can be mobilised to reduce these barriers to the successful delivery of smart city demonstrators.

In line with the findings of this report, the Future Cities Catapult will be directly tackling some of the identified barriers by producing a range of standardised tools, templates and approaches in areas such as contractual governance, ethical assurance and regulator engagement.

Author
Hannah Griffiths, Market Analyst, Future Cities Catapult

For more information about the report please contact:
Finlay Kelly, Project and City Finance Lead, Future Cities Catapult
or **Abigail Matthews**, Project Manager, Future Cities Catapult

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info@futurecities.catapult.org.uk

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