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Smart Cities

"Smart cities" describes places that incorporate a range of technologies (especially those that collect and use data) to address economic, social, and environmental challenges. Projects usually take place in urban areas, but are also deployed in rural settings. This POSTnote looks at smart city innovation in the UK and the technologies involved. It considers the factors driving the adoption of smart city technologies, and the potential benefits, barriers and risks associated with their implementation.

Overview

- Smart city projects can raise productivity, create jobs, improve safety, provide environmental benefits and make public services more efficient and accessible.
- Public investment is helping to drive adoption in the UK, but no one Government department leads on smart cities.
- Barriers to adoption can include a lack of technical skills and funding within local authorities, regulatory hurdles for large-scale projects, and a lack of public trust.
- Projects raise potential issues for inequality, privacy, the security of information and critical infrastructure, and accountability.
- Some projects have also been criticised for prioritising the implementation of new technologies over citizens' needs.

Background

There is no widely agreed definition of a 'smart city'.[1,2] For the purposes of this note, it refers to the use of digital technologies and data to improve places by providing citizens with social, economic, and environmental benefits. Smart city projects are typically tailored to the requirements of a specific place, and can vary from the use of sensors on lampposts to optimise street lighting,[3,4] to operating systems for city-wide management of public services and assets. While the term 'smart cities' is widely used, alternatives such as 'connected places' and 'future cities' are growing in usage,[5] partly to reflect the use of technologies beyond urban settings and to focus on the needs of citizens rather than the technology itself.[6]

Smart city projects may be implemented by local authorities (LAs), universities, transport operators, utility providers or other organisations. Projects have been run across the UK, including in Belfast, Birmingham, Bristol, Glasgow, Hull, Manchester, Milton Keynes, London and Peterborough.[6–19]

Drivers of smart city adoption

Developments in smart city technologies

Technical innovation and decreasing component costs are helping to drive the adoption of smart city technologies, and enabling them to be used in ways that may not have been feasible previously.[20–22] Typically, smart city projects involve the collection, transmission, and analysis of data to inform decision making.[23] This is underpinned by key technologies for sensing, communication, data processing, and information management. Suppliers vary from small and medium sized enterprises (SMEs) that provide a specific technology, to multinational corporations offering a complete smart city platform.[24]

Sensors

Sensors are devices that collect data about their surroundings; for example, to measure air quality, ambient light levels, or river water quality.[25] They can be paired with actuators (devices that control a mechanism) to create real-time feedback loops.[26] Sensor and actuator pairs are key to Intelligent Transport Systems that are used in traffic management across the UK, for example, to vary speed limits or close lanes on roads.[27]

Communication technologies

Smart city systems require communication networks to transmit data. 5G mobile technology (POSTbrief 32) provides broadband connections with faster data transfer rates and lower latency (faster response times) than standard 4G.[28] This may enable the use of technologies currently limited by data transfer, such as autonomous vehicles.[29,30] 5G is expected to increase the number of devices that can connect to a network; by one estimate, it could increase sensor density by up to 12-times.[31]

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Low-Power Wide Area Networks (LPWAN) connect low-bandwidth devices such as sensors (which require only low data transfer rates) over large distances of up to 1000 km.[32] LPWAN are cheaper and use less energy than alternatives such as Wi-Fi. They also have a greater range, and can transmit through buildings and solid ground.[33] This makes them particularly useful for sensor networks inside buildings and infrastructure. For example, a retail park in Slovenia has used LPWAN to create a network of sensors to monitor and reduce water and energy use, by detecting leaks and defective equipment.[34]

Data processing and information management

Developments in computing are making it possible to rapidly process large quantities of data, improving the efficiency of smart city systems and facilitating novel applications.[26,35]

- **Cloud computing** involves transferring data to a data centre for processing or storage (POSTnote 629).[36] For smart cities, it can be used to manage large publicly available datasets, such as those on Bristol's 'BigClouT' platform.[9,37]
- **Edge computing** involves processing or storing data close to the location where they are generated, reducing reliance on the speed of data transfer (POSTnote 631).[38] Consultancy firm McKinsey predict that edge computing will be critical for technologies such as autonomous vehicles, where large amounts of data are processed in real-time.[39]
- **Data analysis** methods vary between projects. Innovative techniques include digital twins (Box 1) that model physical systems to inform (and sometimes execute) changes.[40]

Box 1: Digital twins in urban planning

A digital twin is a digital representation of a physical asset, system, or process, which receives data from its physical counterpart. It uses these data to simulate the impact of an action virtually before making changes in the real world.[41] A digital twin can be used to make changes to its physical twin in near to real-time. For example, if sensors detected a queue of traffic on a road, the digital twin would be updated to reflect this and might signal to traffic lights in the physical world to alter their operation, improving traffic flow.

Digital twins are being used in Singapore, Glasgow, Boston, and Jaipur, to support urban planning.[42,43] They can be used to simulate the impacts of proposed changes, for example, how much additional energy demand a new development might generate.[44] The National Digital Twin Programme is exploring the potential to create a national digital twin for the UK, which would connect digital twins of national infrastructure to a wider network.[45,46] As part of this, the Centre for the Protection of National Infrastructure is developing an Information Management Framework to allow secure and consistent data sharing between digital twins.[47,48]

Public investment

Public investment is also a key driver of the development and deployment of smart city technologies and the infrastructure underpinning them.[49] In 2012, the Technology Strategy Board (now Innovate UK) invested £34.5 m in demonstrating the potential benefits of smart city technologies.[49–51] Feasibility studies in 30 UK cities each received £50,000. Glasgow was given a further £24 m (Box 2),[52] and Peterborough, Bristol and London, an extra £3 m each.[50] In 2015, Manchester received £10 m from Innovate UK to showcase new uses of data and internet-connected technologies, such as air quality sensing, energy reduction technologies, and wellbeing initiatives.[53]

Box 2: Future City Glasgow

From 2013-15, the Future City Glasgow demonstrator developed smart city projects that included:

- **the Glasgow Operations Centre**, a traffic and public safety management system that combines CCTV, traffic management, security systems, and police intelligence to support real-time responses to incidents across the city[54]
- **smart streetlights**, which use 68% less energy than conventional streetlights by adjusting their brightness according to the activity around them
- **travel apps**, to help walkers and cyclists plan their routes. The data collected help inform City Council decisions and are publicly available to enable innovation.[52]

Following the demonstrator, Glasgow City Council established a centre for civic innovation, a data analytics team, and deployed smart streetlights across the whole city. It has recently established a joint smart city working group that brings together city partners to facilitate adoption of smart technologies to support the city's pandemic recovery and sustainability targets.

The Future Cities Catapult and the Transport Systems Catapult were set up by Innovate UK in 2013, to drive innovation and share successful business models. These have since merged into the Connected Places Catapult, which continues to work with cities, industry, academia and government to support innovation and engagement with smart cities.[55]

In 2020, the UK Government announced £5 bn to make gigabit-capable broadband available nationally (with internet speeds of over 1,000 megabits per second).[56–58] High-speed broadband will be an important enabler for some smart city applications. The Government also made £50 m available in 2021-22 to demonstrate the potential benefits of 5G technology.[59] Projects include using augmented reality to enhance tourists' experiences at locations such as the Roman Baths in Bath.[60,61]

Potential benefits of smart cities

Economic benefits

Economic benefits may come from job creation, efficiency and productivity savings,[12] export opportunities for UK businesses,[49] and by making the local area more attractive to live and work in.[62] For example, after £24 m of public funding in 2013, Future City Glasgow (Box 2) reported an initial return on investment of £144 m by 2017 and predicted substantially larger ongoing benefits. Of the local SMEs involved, 63% reported attracting extra business as a result of their involvement.[52,63]

Environmental benefits

Projects can have a variety of environmental benefits, such as:

- **Waste management** – an urban regeneration project in Peterborough is investing £2 m (2020-22) on a waste-to-heat generation plant, connected to a smart electricity network
- **Resource management** – audio sensors have been widely installed on pipes in the UK's water networks to find leaks
- **Reducing environmental impact** – a digital twin (Box 1) for the island of Eday, in Orkney, has been used to improve the efficiency of local energy generation and usage.[16,19,63–65]

Smart city technologies can therefore support progress towards targets such as the UN Sustainable Development Goals, the UK Government's Ten Point Plan for a Green Industrial Revolution and achieving net zero carbon emissions by 2050.[66–68]

Social benefits

Smart city projects can help to improve citizens' quality of life by providing a range of benefits.[69] Examples include:

- making services more convenient to use, by reducing traffic congestion using intelligent transport systems
- increasing public safety, with smart streetlights
- reducing disruption caused by maintenance, by using digital mapping and reporting to coordinate roadworks across utility providers, reducing traffic disruption
- supporting public participation in local decision making, by using QR codes on planning notices that can be scanned with a smartphone to view additional information.[27,34,65,70,71]

Barriers to smart city implementation

Projects may face barriers relating to procurement; public policy; regulation and standards; access to physical assets, data and computing resources; community engagement and trust.

Procurement

Local authority (LA) capacity

LAs may lack the technical skills and information to procure smart city technologies.[72–75] This can make it hard to engage with potential opportunities and to ensure that technologies are resilient and secure.[76] Projects may face challenges from siloed and engrained ways of working inside LAs.[74] They often span multiple LA departments, which can create difficulties for co-ordination, ownership, and implementing changes.[77] The Crown Commercial Service has produced purchasing systems to help the public sector find suppliers for smart city technologies.[78,79]

Funding

A review conducted in 2018 by the Connected Places Catapult noted that smart city funding often focuses on trials proving the technical capabilities of technologies, with relatively little focus on showing commercial viability at scale.[74,77] According to the Institute for Government, the money that LAs had to spend from government grants, council tax and business rates, fell by 18% from 2009/10 to 2018/19.[80] The pandemic has put extra financial demands on LAs,[81] and they may be more hesitant to invest in innovation without a proven return on investment.[72]

Nesta, an innovation charity, reports that the pandemic has shifted LAs towards new operating models, including greater flexibility in staff roles and digitisation of processes. While this focus on digitisation may accelerate some aspects of smart city implementation, re-allocation of staff and changing priorities may reduce LAs' capacity for horizon-scanning and innovation.[82]

Supplier lock-in

There is a risk that LAs or other smart city operators may become "locked-in" to a specific technology or supplier, making it hard to change.[83] In 2018, the Smart Cities All Party Parliamentary Group (APPG) said that central government should create a framework of principles, rules and standards for procurement to help LAs implement smart city projects.[84] Procurement guidance could help LAs to retain more control of projects and associated data, and to avoid lock-in. The use of openly available standards, such as those in the planned Information Management Framework (Box 1), can improve interoperability (enabling different technologies to work together) and help to mitigate lock-in.[47,48,85,86]

Public policy

The Government has not set out a single smart city model for UK cities to follow, saying that this "could conflict with the aims of devolution policy with regard to supporting UK places in addressing local priorities".[49] No single part of central government has responsibility for smart cities policy, which spans several departments. These include the Department for Digital, Culture, Media and Sport (DCMS),[8] the Ministry of Housing, Communities and Local Government,[87,88] the Department for Business, Energy and Industrial Strategy, the Department for Transport, the Department of Health and Social Care, and the Cabinet Office.[8] A few cities, such as Bristol, Belfast and Greater London, have smart city strategies, but most LAs have no published roadmap for smart city implemtation.[6,7,89]

In its 2018 report, the Smart Cities APPG recommended that the UK Government create a strategy to bring together information and guidelines for the procurement and implementation of smart city projects.[84] In the same year, the Policy Exchange think tank said that the successful devolution of cities would depend on smart city initiatives to create data tools that would help Mayors to decide how to direct resources. It recommended that government policy towards city devolution and smart cities should be coordinated.[90] It also highlighted a role for government in facilitating UK exports by promoting the UK's smart cities expertise internationally.[49] DCMS says it is working to ensure that UK smart cities are developed securely and sustainably, with citizen's privacy and local needs at the forefront.[91]

Regulation and standards

Smart city projects may be subject to many different regulatory frameworks, such as those related to planning, utilities, public sector procurement, and use of personal data. Regulatory frameworks are a key factor influencing whether smart city projects successfully scale up. The 2018 review by the Connected Places Catapult reported that in general, UK regulators welcomed smart city projects and were open to granting regulatory concessions for small, temporary demonstrators.[74] However, many projects failed to scale-up when faced with the real-world regulation and market forces that they had been exempt from as demonstrators.

Standards can help to ensure the safe and ethical use of technologies. The British Standards Institution (BSI) has developed some standards specifically for smart cities.[92–98] It also represents the UK internationally, at the International Standards Organisation, which has produced a series of standards for smart cities.[99–102] BSI and the Centre for the Protection of National Infrastructure (CPNI) have published a specification that defines good practice for safeguarding data and information security in cities, and other guidance for applying a security-minded approach to implementing smart cities.[47,97]

Access to physical assets

The complex ownership of public space and assets can pose challenges for smart city projects in the UK. Privately owned transport services and utilities such as electricity, water and gas, may make implementation harder, as agreements between public and private organisations must be negotiated.[23,72] One study found that over half of UK LAs had private-finance initiative agreements in place for the management of their

assets and services in 2017.[74] These can make the use of public assets more difficult, and may give the private entity ownership of any data created through the use of the assets.

Access to data and computing resources

Smart city projects often require the use of both publicly and privately owned data. Negotiating data sharing can be a barrier to implementation. Non-disclosure agreements have been used to secure access to data, but concerns over data misuse or breaches, as well as competitors gaining access to data, have been reported as common barriers to data sharing.[74]

When data is shared, it may not be in a standard format. This means that additional processing is required to make datasets usable. Using agreed standards for data output can help to address this, such as those in the Information Management Framework (Box 1) and those recommended by the Data Standards Authority for data sharing across government.[47,103,104]

The cost of computing resources may also be a barrier in some cases. For instance, if a smart city system uses real-time sensing technology and produces large volumes of data that require rapid processing.[20]

Community engagement and trust

Positive community engagement can help to drive smart city adoption,[105,106] and smart city projects can increase citizens' engagement with government and their community. However, a lack of public engagement, understanding and trust can be a major barrier to the development of projects.[107,108] The Connected Places Catapult's 2018 review reported that projects historically gave citizens little chance to engage with the design and deployment of new technologies.[74] However, awareness of the role that user engagement plays in project success had grown, as had efforts to be more open and participatory.

Smart city projects have been criticised for prioritising the implementation of novel technologies over the needs of citizens.[109,110] In some cases, technology may be used to solve a problem (potentially creating additional privacy and security issues) when a non-digital solution may have been possible.[111] Public-engagement methods can help to ensure a project serves the needs of citizens by inviting the public to contribute to project design, for example through co-design workshops.[74]

Potential risks associated with smart cities

Smart city projects may have the potential to increase inequality, create security risks, and to undermine privacy.

Inequalities

There is a risk that the potential benefits of smart city technologies may not be experienced equally by rural and urban communities. Increasing digitisation may also widen inequalities for some groups.[23]

Rural and urban divide

Smart city technologies can be deployed in rural settings. For example, the 5G Rural First project has been using temperature sensors to monitor water quality in Orkney to help prevent bacteria such as legionella.[112,113] However, most projects have focused on cities. By 2050, 66% of the global population is predicted to live in urban areas,[114] and innovation in cities may lead to rising inequality for those in rural areas.[115] There may also be potential for a growing divide between urban areas. For example, if some develop better digital infrastructure as a result of long-standing strategies focusing on digital innovation.[23,116]

Digital exclusion

Digital systems have the potential to exclude groups who do not have access to the internet, devices such as smartphones, or the digital skills required to use them. For example, LAs that use smartphone applications to collect citizen responses (such as Fix My Street, for reporting maintenance issues), may disproportionately focus on the needs of younger and wealthier citizens.[23,117] In addition, smart cities might further increase inequality as more jobs involved in public service delivery may require advanced digital skills.[23,118,119] This may place those without such skills at greater risk of unemployment.

Security

The National Cyber Security Centre (NCSC) recently raised concerns over the potential use of smart city technologies for espionage, surveillance, and the collection of sensitive data.[120] Smart city systems that monitor public services may produce data that could present a security risk, such as information about vulnerabilities and patterns of usage.[121] In addition, projects are likely to involve multiple connected technologies and systems. This interconnection has the potential to reduce a city's resilience.[122] Unexpected disruptions may have greater impact, as their effects spread through connected systems.[123] In 2020, CPNI and NCSC reported that they had increased engagement with LAs to provide advice on securely developing and implementing new smart city systems and managing the information generated.[124] In May 2021, NCSC issued guidance for UK authorities responsible for the design, build and operation of smart city systems, to help make them easier to manage and more resilient to cyber attack.[125]

Concerns have also been raised by human rights groups and academics about the level of control over public spaces that smart city projects could give to industry.[126,127] Amnesty International suggests that outsourcing smart city operations to private companies may result in an increase in "unaccountable power", with local government having little control over infrastructure, operations, and the data generated.[127]

Privacy

Data protection measures can help to make data more secure (POSTnote 468), such as anonymising data by removing details that identify individuals. However, links between datasets may make it possible to re-identify individuals.[128] As this becomes more likely when small groups of people are involved, members of minority groups may be most at risk of re-identification.[129]

Human rights groups and legal experts have raised concerns that legal protections for the use of personal data are insufficient for data gathering projects such as smart cities,[111,127,130–134] and that there is a lack of monitoring and auditing.[134–136] Privacy International suggests that reduced anonymity through greater use of surveillance technology may undermine an individual's ability to protest, affecting democratic rights.[111] The Smart Cities APPG suggested that the Government should consider establishing auditors for smart cities.[84]

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