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Smart technologies create opportunities for urban development and regeneration, leading to a proliferation of projects/programmes designed to address city strategies around environmental, economic and social challenges. Whilst there is considerable critical debate on the merits of smart city developments, there has been surprisingly little research on the evaluation of smart interventions, and the outcomes of embedded smart technologies for cities and citizens. This examines case-study research undertaken in Birmingham, Bristol, Manchester, Milton Keynes and Peterborough, on city approaches to smart city evaluation and reporting. Findings exemplify contemporary city evaluation and reporting practices, challenges and recommendations to support smart urban development.

Keywords: Smart city, urban indicators; smart city evaluation, innovation programmes; UK cities; smart city reporting

Introduction

Global trends towards urbanisation are associated with wide-ranging challenges, creating complex pressures on environments, infrastructures, buildings, networks, resources and people in cities and regions. Cities account for an estimated 60-80% of global energy consumption and 75% of carbon emissions (UN 2015), although they generate an estimated 80% of global Gross Domestic Product (Bis 2013a), whilst covering approximately only 2% of the world's land mass (UN 2015). Some 54% of the world's population now live in urban areas, and this is predicted to increase to 66% by 2050, although higher proportions of national populations already live in European cities (UN 2014). Cities therefore need to develop the infrastructures, systems and services to help citizens live, work, play and travel - ensuring cities can develop economically, whilst protecting the environment and quality of life for citizens.

Smart technologies offer solutions for new integrated city systems, infrastructures and services provision (BSI 2014a, 7), and create opportunities for urban

development through developing data intelligence, digital entrepreneurship and innovation. Whilst there is considerable critical debate on the merits of smart city developments, there has been surprisingly little research on the evaluation of smart interventions, and the outcomes of embedded smart technologies for cities and citizens. This paper first examines the background to the smart city vision and the evidence for alleged smart city benefits, the development of smart city indicators and frameworks, and the challenges around the development of urban indicators with particular attention to indicator validity, measurability, representation of complexity and utility. Second, this examines case-study research on city approaches to evaluation and reporting of their smart city work, undertaken in five cities in the United Kingdom; namely Birmingham, Bristol, Manchester, Milton Keynes and Peterborough. This exemplifies contemporary city evaluation and reporting practices, the challenges faced by city authorities, and recommendations to inform city practices around smart city development and evaluation.

Background

The smart city vision

Smart cities have become a prevalent vision of future cities (Moir, Moonen and Clark 2014), replacing more narrowly defined visions of the 'Digital city', 'Intelligent city', 'Virtual city' and 'Ubiquitous city' (Albino, Berardi and Dangelico 2015, 5). The smart city vision may also encompass city visions around: the environment (e.g. sustainable, eco, green and resilient cities); society (e.g. inclusive and liveable cities); economy (e.g. entrepreneurial, competitive, innovative and global cities); and governance (e.g. intelligent and efficient cities) (Moir, Moonen and Clark 2014, 4). Tracing the historical roots of smart cities, Kitchin (2015) identifies several influences including: mid-

twentieth century modernist, rationalist urban planning; 1970s urban cybernetics focused on monitoring and control systems; 1980-1990s neoliberal ideologies driving corporate and entrepreneurial urban governance; and developments in city-integrated Information and Communications Technology (ICT) infrastructure and networks.

Whilst there are a large number of definitions of smart cities (Albino, Berardi and Dangelico 2015), there are two key strands of scholarship, the first focuses on urban development through enabling a technology-focused knowledge economy, and the second focuses on improved public sector operations from government use of technology driven by corporate ICT development and cross-sectoral innovation (Goodspeed 2014). Key smart city characteristics include: the integration of ICT infrastructure and technologies (BSI 2014b); digital transformation of urban systems (BSI 2014b); the centrality of big data (Bis 2013a); and multi-stakeholder/actor engagement (EU Directorate-General 2014). Smart cities may also be understood in terms of their development maturity based on the International Data Corporation (IDC) city benchmarking studies (IDC 2013), which allows for the inclusion of both micro-scale interventions characteristic of the mature retrofit city, and macro-scale Greenfield developments (Shelton, Zook and Wiig 2015).

The British Standards Institution (BSI) presents a techno-utopian smart city vision that seeks to be citizen-centred and digital, build on open data and enable collaborations (BSI 2014b). However, the vision of smart city benefits is heavily-contested (Townsend 2013; Greenfield 2013; Kitchin 2014, 2015; Hollands 2014; Glasmeier and Christopherson 2015). Critical debates on the potential dystopian effects of smart city developments raise concerns associated with: technocratic governance; the corporatisation and marketisation of governance; technological lock-ins; hollowed-out state services; citizen surveillance and privacy; equality and inclusion issues; and the

politics underpinning big data analytics (Kitchin 2014, 2015). Such critical concerns raise questions about both the merits of smart city approaches to urban development, and the evidential base for impacts in the 'actually existing smart city' (Shelton, Zook and Wiig 2015, 14).

Surprisingly little research has been conducted on the evaluation of smart city interventions, and the measurement of the outcomes of embedded smart technologies for cities and citizens. A review of international case studies criticises the evaluation approaches adopted by smart cities, as non-standard and inadequate, and more focused on implementation processes and investment metrics than city outcomes (Bis 2013b). However, some smart cities are beginning to examine metrics to evaluate the impacts of programmes on people's lives, for example Rio de Janeiro is looking at citizen value, and Boston is evaluating city benefits (Bis, 2013b). Another approach presented in the 'Mapping Smart Cities in the EU' report evaluated smart city projects (e.g. Smart neighbourhoods, Testbed micro-infrastructures, Resource management systems, Intelligent systems, Citizen participation platforms) based on types of projects, goals, targeted stakeholders, project scalability, level of citizen engagement, and applicable measurable success outcomes (EU Directorate-General 2014). However, neither of these research studies applied standardised measurement indicators, nor offered methods to evaluate impacts on the city. Further research is needed to evidence and explicate the 'smart urbanism' phenomena transforming urban contexts (Luque-Ayala and Marvin 2015, 2106), and to evaluate the impact of smart city interventions on urban outcomes and governance.

Smart city indicators and the development of frameworks

Extensive reviews of city indexes (such as Moonen and Clark 2013; Joss et al. 2015) have identified surprisingly few smart city indicator frameworks and models specially

designed to support city evaluation and benchmarking. These include the *Smart City Maturity Model*, which identifies five smart city maturity phases, moving from the 'Ad hoc' project planning phase to the ultimate 'Optimised' city-wide city of systems phase (IDC 2013); the *Smart City Reference (SCR) Model* which conceptualises smart city development stages in terms of seven interconnecting city layers with Key Performance Indicators (KPI) to support sustainable development (Zygiaris 2013); the *European Smart Cities Ranking (ESCR) Model* which offers a comprehensive smart city indicators framework defined across six city characteristics/dimensions, including Governance, Economy, People, Living, Environment and Mobility (Giffinger et al. 2007); and the Smart Cities Council's *Smart City Index Master Indicators* (SCIMI) framework which measures Smart Government, Economy, People, Living, Environment and Mobility dimensions, to enable ranking of cities against liveability, workability and sustainability indicators (Cohen 2014). Also relevant are industry-led indexes including: *The Ericsson Networked Society City Index* which measures the ICT maturity of cities across ICT Infrastructure, Readiness and Usage indicators against Economic, Social and Environmental Impact dimensions (Ericsson 2014); IBM's *Smarter City Assessment Tool*, which focuses on assessing cities' capabilities as instrumented, interconnected and intelligent (ibm.com) (IBM 2009); and the PricewaterhouseCoopers/Partnership for New York City (2014) *Cities of Opportunity Index* which measures the 'Smart', 'Quality of Life' and 'Economic' indicators of leading cities.

The European Innovation Partnership on Smart Cities and Communities (EIP-SCC) observed that there is no standardised smart city indicator framework widely-accepted by cities to measure city performance; and available to evaluate progress against city strategies aligned with measurement indicators (EIP-SCC 2013). However, considerable development work is currently on-going to address smart city evaluation

and measurement. This includes work on standards relevant to smart city development, by the International Standards Organization (ISO), European Committee for Standardization (CEN), BSI, and other national standardisation organisations (SSCC-CG 2015). BSI's work on smart city measurement builds on the Smart City Framework, Publicly Available Specification (PAS)181 standards (BSI 2014b). There is also significant work on evaluation driven by the European Commission (EC). This includes the EUROCITIES CITYKeys initiative, which provides EC funding for cities to develop and validate smart city measurement frameworks and measures of KPIs; and also data collection procedures to support standardised, transparent European-level monitoring, enabling comparability of smart city solutions across European cities (citykeys-project.eu).

Much of the work on smart city indicators seeks to situate itself in the 'sound science' paradigm for developing measurement indicators, whereby the ideal set of indicators is considered to follow a rational approach to the design of valid, measurable and transparent indicators for a defined purpose and audience (Holman, 2009). This aspiration is evident in the EIP-SCC (2013) recommendations that an effective smart city indicator system should address strategic, political and operational levels; establish measurement overtime based mainly on real-time data; be evidenced against baseline measures and strategic targets with consistent and comparable urban data; develop through a stakeholder process that engages relevant research and community groups, whilst being open to improvement and the integration of future innovations; build on existing urban development indicator systems aligned with typologies of European cities; offer open reporting on progress and support cities' evaluation of their progress towards becoming smart cities through city benchmarking and intercity comparisons.

However, there is a lack of clarity about the best approaches to measure the contribution of smart city solutions to city performance (BSI 2014a), and to urban development.

Challenges for the development of smart city indicators

Relevant to smart cities, the discourse on urban and sustainable development indicators draws attention to challenges of indicator validity, measurability, complexity and utility. The challenges address: developing valid approaches to mapping indicators and metrics onto standards (BSI 2014b; EIP-SCC 2013) and goals (SDSN 2015); the measurability of tangible and/or intangible indicators to support comparability (Holman, 2009); the representation and measurement of complexity in urban systems (Arnold 2004; Holman 2009); and designing standardised smart city indicators with utility and value for different purposes and urban contexts (EIP-SCC 2013; BSI 2014b)**.**

The challenge of establishing theoretical validity is illustrated through a comparison of the ESCR Model (Giffinger et al. 2007) and the SCIMI framework (Cohen 2014), which both measure similar city dimensions, albeit against different factors, indicators and metrics. The ESCR Model Smart Environment indicators focus on the natural environment, whereas the SCIMI focuses strongly on urban planning and the built environment. Similarly, both have Smart Mobility indicators, although the ESCR Model offers only one ICT-related factor, namely the 'Availability of ICT-Infrastructure', whereas the SCIMI offers a large number of ICT indicators.

Drives towards comprehensiveness create large numbers of indicators and measures, whilst not necessarily addressing measurability issues (Holman 2009) and indicator gaps (SDSN 2015). This is illustrated by the ESCR Model's lack of provision of indicators and metrics for the difficult-to-measure Smart Governance Participation factor 'Political strategies & perspectives' (Giffinger et al. 2007). Indicator measurability is supported by appropriate data collection; this collection needs to

address different data sources and collection jurisdictions (Giffinger et al. 2007; Cohen 2014; Ericsson 2014; PricewaterhouseCoopers/Partnership 2014); data provenance and ownership (Moonen and Clark 2013); comparability and interoperability (BSI 2014b); and the practical issues of resourcing timely data collection (SDSN 2015).

A challenge for developing urban indicators is how to represent the complexity of dynamic, evolving, open and unbounded urban systems (Arnold 2004); the interrelationships between slow-changing urban forms and faster-changing urban flows (Williams 2014); the interacting social, economic, political, technological and environmental factors in urban systems that are shaped by virtuous and vicious system feedbacks, and cumulative historical causation (Arnold 2004). Such complexity is evidently not represented in the smart city indicator frameworks and models (Giffinger et al. 2007; Zygiaris 2013; IDC 2013; Cohen 2014).

An interesting question is how urban indicators should address issues of scale applicable to smart city innovation, which is initially, typically, implemented at micro-scale; and how to achieve correspondence between micro-level indicators and macro-level indicators to reveal urban development and performance. Science Technology Studies have an established history of evaluation scholarship relevant to urban innovation policy (Arnold 2004; Edler et al. 2012; Magro and Wilson 2013). This recognises complexity in multilevel urban systems and subsystems; the embedded innovation subsystem operating dynamically within the urban systems context; and the related evaluation subsystem, which is designed to identify the value, impacts and consequences of the innovation (Arnold 2004). Further areas of complexity are observed by Holman (2009) in linking sustainable development systems to indicator systems, and systems of governance and policy actions.

Debates on the utility and value of standardised smart city indicators need to address whether indicators can support: the demonstration of benefits for cities and citizens (BSI 2014b); monitoring and measurement of performance and progress (BSI 2014b; EIP-SCC 2013); evaluation of progress against city strategies (EIP-SCC 2013); and city benchmarking and intercity comparisons (EIP-SCC 2013) applicable to different city contexts (population size, geography, scale etc). Furthermore, Holman (2009) argues that indicators should be policy instruments designed to have clear links to policy changes, and an innovative utility for local governance.

Emerging from this review are questions around how local government authorities approach the evaluation of smart city programmes and projects in 'smarter' cities; how macro/micro-level considerations are resolved in evaluations of smart city work at project, programme and city-levels; what influences city authority-led approaches, including the role of big data and analytics; how current approaches contribute to evaluations of smart city developments and city performance; how outcomes are reported through governance processes; and what are the consequences for city actions and decision-making.

The SmartDframe project

This section presents the objectives, sample, methods and findings of the SmartDframe project.

Research objectives

To support future city strategies and smart city development, it is important to understand the benefits (and disbenefits) of smart city work for cities and citizens, by examining local authority practices of evaluation and reporting and the value of data intelligence driving these processes. The objectives of the SmartDframe project, which

is linked to the MK:Smart programme (mksmart.org/), are to examine city approaches to the evaluation of smart city projects and programmes, and reporting of city outcomes and impacts, through a series of contemporary case studies in 'smarter' cities in the United Kingdom (Caird, with Hudson and Kortuem 2016).

Sample

Local government authorities representing a selective number of 'smarter' UK cities were invited to participate in the case-study research, including Birmingham, Bristol, Manchester, Milton Keynes and Peterborough. Representatives of Glasgow City Council and The Greater London Authority were also invited, although not included in the study at this stage. Figure 1 presents a brief overview of the participating cities and their key smart city initiatives.

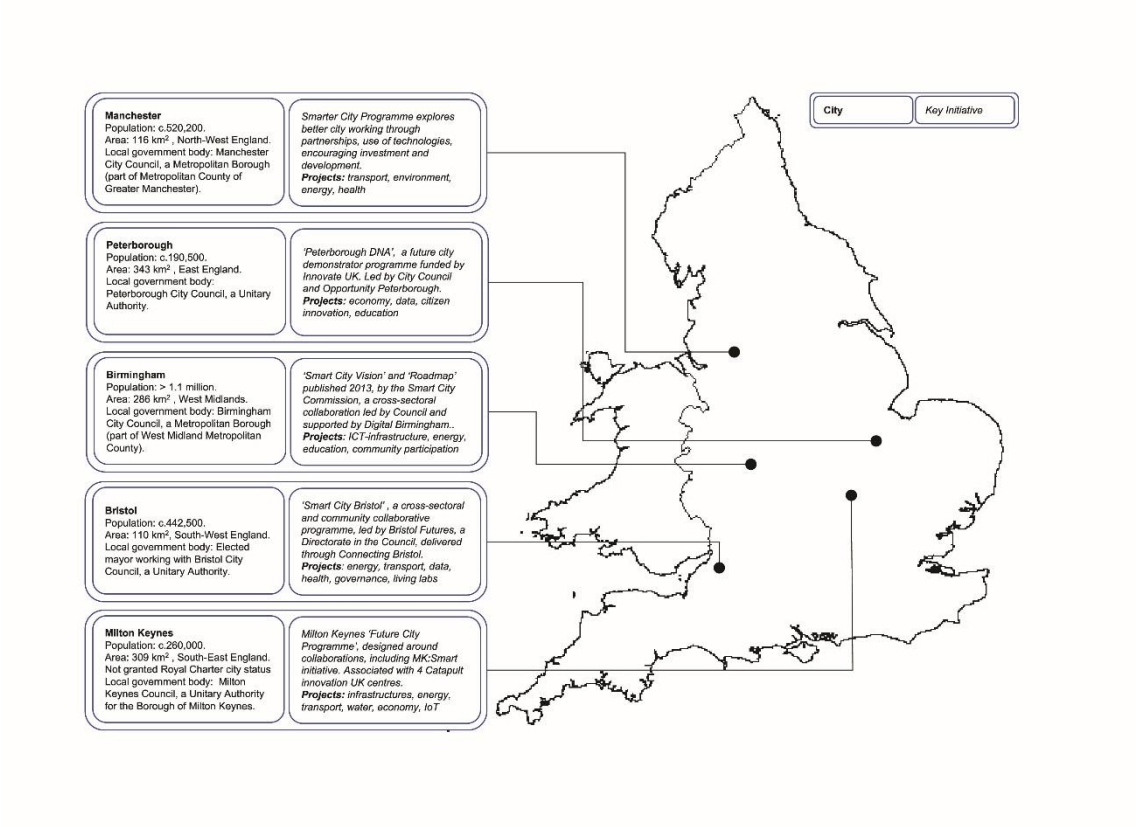

Figure 1. Overview of UK smart cities and key initiatives

The EU Directorate-General found that nearly 90% of EU cities with over 500,000 inhabitants are smart cities already, based on their own definition of a smart city as "… a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership" (EU Directorate-General 2014, 9), which included the larger cities of Birmingham and Manchester. Moreover, 51% of all EU cities have at least proposed or implemented smart city initiatives (EU Directorate-General 2014), which included all five cities under consideration in this analysis. The cities were selected because they were active in having a large number of smart city projects and programmes; and being strongly involved in key smart city networks, for example EUROCITIES, EIP-SCC, Small Giants and UK Core Cities. These cities exemplify the mature retrofit smart city in the global north, where Greenfield smart cities are exceptional (Shelton, Zook and Wiig 2015).

The selected cities represented different population sizes, considered a useful indicator for city stratification. According to the EC classification (EC 2012, 5): Birmingham is an XXL-sized city (over 1,000,000 inhabitants); Manchester an XL-sized city (500,000-1,000,000 inhabitants); Bristol and Milton Keynes (as a new city) represent large-sized cities (250,000-500,000 inhabitants); and Peterborough a medium-sized city (100,000-250,000 inhabitants). Small cities with populations of 50,000-100,000 and global cities with more than five million inhabitants were not included in the study.

Methods

Local government authorities, representing Birmingham, Bristol, Manchester, Milton Keynes and Peterborough, were interviewed during 2015. The study focused on city authorities to explore their role in the evaluation of smart city interventions, and the consequences of evaluation outcomes for influencing urban governance and

development decisions. However, city authorities do not always lead the development and partnerships around smart city projects and programmes, and therefore, the SmartDframe project could be extended to include interviews with industry and other city actors leading developments. The interview questionnaire was designed around open-ended questions to investigate three key areas as follows:

- Cities' approach to evaluating smart city work. This addresses issues of: strategic leadership; stakeholder partnership and engagement; key influences on evaluation approaches; and actions to develop evaluation frameworks, with reference to success indicators, measures and data.
- Effectiveness of cities' evaluation of smart city work. This addresses: development and improvements; views on relevant evaluation work; and contribution of city work to intercity comparisons and city learning.
- Cities' approach to reporting smart city work. This addresses the contribution to city reporting, governance and decision-making around urban development.

Subsequent case study analyses were based on reviews of city reports and interviews with key local government authorities; and represent the practices and opinions of the city authorities at the time of interview (Caird 2016).

Findings

The case-study analysis of findings on city approaches to smart city evaluation and reporting are summarised in Table 1, and discussed with reference to: their smart city programmes and projects; focus on project evaluation; influences on their approaches; city-level plans for evaluation; views on the need for a smart city evaluation framework; development of city data intelligence; reporting through city processes; and the influence of their smart city work on urban development decisions.

	Evaluation approach - *Plans*	Reporting
Manchester	Project-focused evaluation driven by external funders. Programme is not currently contributing to city performance frameworks, e.g. city performance management framework, community strategy dashboard and Annual-State-of-the-City indicators. Some high-level strategic success indicators are monitored and evaluated e.g. CO_2 emissions. Involved with BSI PAS(181) and CITYKeys initiatives. Conducts city benchmarking activities. Leading EUROCITIES work on high-level city evaluation. *Working on EC-funded project with universities to develop an Impact Assessment Framework with potential to scale to city and link to strategies and performance measures.*	No smart city reporting dashboard. Reporting primarily to funders. Political structures are used to report projects more widely. Needs interoperability across project reporting criteria.
Peterborough	Beginning to consider evaluation. Funders are focused on development not evaluation. Helped shape BSI Smart City Framework and PAS Standards, including benefit mapping, tracking and baselining of project/programme outcomes. *Working with universities to implement an evaluation programme. Initially focusing on qualitative success indicators and using data and smart tools to support businesses.*	Reporting to funders. Informal reporting through forums.
Birmingham	Project-focused, partner-led evaluation with baselines established for monitoring. Big projects have KPIs. Influenced by BSI PAS(181), Maturity Frameworks and EC initiatives (Smart City Lighthouse, CITYKeys). Have not established Smart City Roadmap KPIs. Difficult to measure city outcomes and no funding available. No overall evaluation of programme outcomes. Conducts city benchmarking activities. No integration of programme outcomes at city-level. *Plans to work with KPMG consultants on evaluation of programme outcomes once the deliverables become mature. Plan to develop a framework using BSI's PAS(181).*	Reporting to funders. Digital Birmingham leads quarterly reports to Smart City Commission (SCC). SCC reports on some city outcomes, e.g. health, transport, energy/climate. High-level reporting by SCC to the Cabinet Member.
Bristol	Project-focused, funder-driven evaluation with baselines and KPIs established for measurement. No overall programme evaluation. Conducts city benchmarking activities. *Interested in establishing a formal evaluation panel engaging citizens/stakeholders to examine city progress. Considering aligning the programme activities directly to the city strategies, Mayor's Vision, the corporate plan & outcomes to demonstrate impacts.*	Reporting to funders. Informal reporting to open stakeholder meetings and forums. Annual reviews by Connecting Bristol, reporting to Bristol Futures Directorate.
Milton Keynes	Project-focused, funder-driven with baselines and KPIs established. Demonstrations of early-stage projects. Too early to determine community benefits. MK:Smart offers a hard evaluation framework for the initiative and relevant audiences. Does not benchmark against other cities except for high level outcomes e.g. CO_2 emissions. *Working on development of a smart city roadmap. This could be aligned with a strategic city-level evaluation approach that is adaptable and flexible.*	Reporting to funders. No overall formal reporting process for Future City Programme. Some reporting on progress to city stakeholders and politicians.

Table 1: Summary: City approaches to smart city evaluation and reporting

Smart city programmes and projects

The local government authorities understood the smart city concept in terms of their smart city and future city programmes, which involve partnerships between business, universities, the community and the public sector (figure 1). Some programmes were Council-led, as follows.

- Manchester's 'Smarter City Programme' values strong partnerships to explore better city working and encourage investment and development.
- Milton Keynes 'Future City Programme' is designed around collaborations through projects and programmes (including the MK:Smart initiative), and is associated with UK Catapult innovation centres.

Other programmes were led by Councils and their Directorates, as follows.

- Birmingham's work on the 'Smart City Vision' and 'Roadmap' is led by the Smart City Commission. This includes the Council and leading figures from different sectors, supported by Digital Birmingham, the city's digital partnership.
- 'Smart City Bristol' was established by Bristol Council as a collaborative programme between different sectors and the community, led by Bristol Futures (a Directorate in the Council) and delivered through Connecting Bristol.
- 'Peterborough DNA' is a future city programme led by Peterborough City Council and Opportunity Peterborough, and funded by the Innovate UK, Future Cities Demonstrator competition.

The cities were in early smart city maturity phases based on city maturity indicators (IDC 2013). An exception was Birmingham, the only city with an established Smart City Commission and 'Smart City Roadmap', although Manchester and Bristol

cities were also considering whether to develop a Roadmap. The cities had a range of smart city projects, usually not implemented at city-scale across the economy, education, energy, environment, citizen innovation, community participation, data, governance, health, ICT-infrastructure, city infrastructures, Internet of Things (IoT), living labs, transport and water etc. (figure 1). However, the smart city future vision is only one vision of many guiding urban development, and the cities had a range of projects and programmes based around their challenges and interests, for example in the 'sharing economy' and 'liveable cities'.

Project evaluation

The cities' approach to smart city evaluation was currently focused at a project level, where evaluation and reporting on KPIs was part of the project delivery, conducted with and through city partners. Evaluation was primarily influenced by their external funders' requirements driving the evaluation agenda.

Funders' evaluation requirements were varied: for example EC funders require application of clear measurement indicators with Smart Cities and Communities Lighthouse projects (ec.europa.eu) to support obligatory data-sharing across European-funded projects; whereas HEFCE funders of Milton Keynes MK:Smart programme (mksmart.org) require regular reporting, including qualitative and quantitative information to communicate progress; whereas Innovate UK funders of Future Cities Demonstrator projects in Bristol (connect.innovateuk.org) and Peterborough (peterboroughdna.com) currently placed more importance on the cities' demonstration of their innovation projects, although were beginning to address wider evaluation issues. There was recognition that standardisation across the requirements of funding bodies would be helpful as interoperability of reporting criteria is an issue.

Most of the cities were in early maturity phases of their smart city development (IDC 2013), where demonstration of the validity of smart innovation solution concepts through monitoring and measurement may be an appropriate 'initial' evaluation before projects can be scaled to the city-scale. Manchester authorities said '…Inappropriate evaluation could kill a good idea if conducted too early'. Milton Keynes and Peterborough authorities were also cautious of premature evaluation of what were typically innovation projects, fearing this might crush the opportunities arising from smart city work.

Establishing baseline measures for projects was considered a good approach to demonstrate validity and progress. Several cities, such as Birmingham, Bristol and Milton Keynes have already established KPIs and measures for projects; although only Birmingham had a formal Smart City Roadmap helping to establish actions and measures of progress towards smart city targets. Birmingham authorities recognised the importance of establishing baselines for monitoring and measuring progress, and for identifying projects with the biggest city impacts and replication potential. Moreover Peterborough authorities intended to establish baseline measures from the outset with Phase 2 of their DNA programme.

Even when baselines have been established to monitor progress, several cities recognised the difficulty of proving the value of smart city projects and interventions, and identifying the causal effects on targeted city outcomes. Milton Keynes authorities recognised that developing and measuring progress indicators of smart city projects were much easier than measuring their impacts on city outcomes. With MK:Smart they attempted to develop a hard evaluation framework, although noted the difficulties of showing the cause-effect relationships linked to smart city projects. Milton Keynes authorities said:

> …While strategic approaches are required; setting outcomes you want to achieve and measuring whether you are; there are challenges! Tracking the extent to which smart city projects have enabled economic and housing growth of a city, and drawing the linkages between the two is difficult. It's difficult to show the causal link and relationship.

Birmingham authorities also acknowledged difficulties with attributing causality to smart city activities even when the baseline measures reveal progress.

External influences on approaches to evaluation

The cities' evaluation practices reflected an awareness of ongoing smart city evaluation work, such as the BSI work and the EC-funded EUROCITIES CITYKeys programme (citykeys-project.eu). Birmingham and Peterborough authorities were familiar with the Smart Maturity Model (IDC 2013). Most of the cities were aware of the BSI Smart City Framework PAS(181) guidance on principles and performance standards in programme implementation, with reference to critical strategic and operational success factors (BSI 2014b). Moreover, the EC's increasing emphasis on evaluation has been influencing the cities' operations, including through Birmingham and Manchester's involvement with the CITYKeys project.

Macro-level city plans

The city authorities intended to undertake evaluation at the city-level, and most were already working in partnerships mainly with local universities, to address evaluation challenges within their future and smarter city programmes. Although most had not developed advanced evaluation plans, Birmingham had made significant progress in developing a city-level evaluation framework aligned with their smart city strategy and Roadmap. They had already conducted research examining various evaluation frameworks, models and standards, including the Smart City Maturity Model

(IDC 2013), and ISO 37120:2014 Sustainable Development of Communities – Indicators for City Services and Quality of Life (iso.org), and had worked with Arup to trial an energy-focused smart city framework. They were also planning to work on evaluation with a global professional service company, operating at the forefront of data science, once they progress the delivery of the city Roadmap. However, their priority was to get projects operational, and '…they did not want to get side-tracked on measurement'. Nevertheless they recognised '…It is not just about delivering projects, what we want to do is identify where we are making the impacts, how we get things to change, what difference we are making to citizens and businesses'.

Through Manchester's work on the Advisory Board for CITYKeys, they were leading smart city benchmarking work, comparing cities across strategic city areas, including economic development, governance, city infrastructure, transport, energy and citizen engagement. Manchester was also developing an Impact Assessment Framework in partnership with universities, for one of their European-funded smart city projects Triangulum (triangulum-project.eu), where they planned to address city-level impacts. They said '…Triangulum is providing the basis to get the Framework right, dealing with energy, transport, dealing with people; it's got the basic ingredients of the impact framework. Once it's working well it can be expanded in scale, geographically and thematically'.

However, most of the cities had not yet adopted an effective evaluation framework to measure impacts of smart city work on wider city outcomes. Milton Keynes authorities had developed many measures through their MK:Smart programme which could contribute to a smart city evaluation framework, although they faced challenges proving the impact of specific projects on city outcomes. Peterborough authorities were beginning to consider their approach to impact assessment, following

an initial evaluation that aimed first to improve their future city 'DNA' programme, then reduce the complexity of projects and address project scalability issues. Manchester and Milton Keynes authorities regarded smart city evaluation as being at an early stage, and did not think any cities had established a full evaluation programme yet. Birmingham authorities acknowledged that no accepted evaluation approach to smart city work had emerged as yet.

Need for smart city evaluation

The city authorities have started to look at potential evaluation frameworks for their smart city programmes, although had questions about the validity and meaningfulness of the available evaluation frameworks. Bristol authorities emphasised that the design of smart city evaluation should reflect a vision of smart cities that is more about cities being liveable, and achieving quality of life outcomes for citizens and less about cities being digital. Bristol authorities said:

> Evaluation needs to relate to how Bristol is a better place to be, how your life has improved or how you can get a better job, rather than based solely on quantitative measures, such as the number of intelligent lights you have got in the city or how much of the city is covered by Wi-Fi. The outcomes of becoming a smart city are not digital…they are about how it feels to be in that city; smart cities are about liveable cities.

Birmingham authorities were aware of considerable work on smart city evaluation, although were critical that many evaluation frameworks were based on an arbitrary selection of indicators; and were focused on what is easily measurable rather than what should be measured or became too specific about what a city had to achieve to become smart, when they regarded smart cities as multi-faceted. They also raised concerns that smart city evaluation might become a city popularity contest, when

comparing and benchmarking cities would not necessarily reflect the different challenges faced by cities.

The cities offered recommendations for the design of smart city evaluation. Birmingham authorities believed this should help to identify gaps and opportunities in cities' smart city work through intercity benchmarking. Similarly, Milton Keynes authorities suggested that an effective evaluation framework should inform cities of the potential for different smart city approaches and technologies, so they could identify their strengths and weaknesses. An effective evaluation framework should also have a built-in flexibility and be adaptable to different city circumstances. Moreover, Peterborough authorities recognised they needed a more formulated framework embedded in their smart city work that would be capable of evolution, in response to new data collected as their work develops. Peterborough authorities said:

> We need to have more of a formulated framework that we can assess against, but we also recognise that it will continue to evolve as well, because as we learn more, get more involved and have more access to more data, that influences what we do. We understand that it won't be set in stone.

Several city authorities questioned whether a smart city evaluation framework with specific smart city KPIs is needed for evaluation, when city councils were typically more concerned with meeting statutory reporting obligations, and providing data and measures associated with strategic city outcomes. Whilst some city strategies, and Council Plans and Actions are statutory documents, at present city councils have no obligation to have a smart city strategy or roadmap, or to evaluate this outside the requirements of their external funders.

Birmingham, Bristol and Manchester authorities mentioned that they are already obliged to measure a large number of city KPIs against their city strategies and actions. At a time when cities including Bristol were making moves to reduce the number of

KPIs, some cities were considering whether it is valuable to add a new suite of additional smart KPIs for measuring smart city outcomes. Instead some cities preferred to evaluate the contribution of smart city work to existing city KPIs aligned with strategic city outcomes. Bristol authorities suggested that '…You just need KPIs about improving the general quality of the city and the contribution made by introducing advanced smart technologies', rather than adding specific smart city KPIs, which they considered potentially unnecessary and counterproductive.

City authorities acknowledged that they faced challenges to align smart city activities with their wider city strategies, and to demonstrate the impacts on city outcomes. Bristol authorities mentioned they need to align their smart city activities with strategies, such as the Mayor's Vision for Bristol. In Birmingham, the city authorities were interested in evaluating the collective impacts of projects to inform city outcomes, and planned to ensure their smart city demonstrator projects have direct measurable city impacts in specific strategic areas, for example on city health and employment outcomes. Similarly, Peterborough authorities were developing plans to focus on their city challenges and strategies, and map the key metrics and data sources available for use, to assess the outcomes of their smart city work.

Developing data intelligence

The cities' practices reflected an interest in developing data intelligence through their smart city work. New mechanisms for city data generation, collection and sharing, including through data hubs, were helping city authorities develop the value of data intelligence, and this was beginning to inform city strategies. Birmingham authorities have started to explore how data intelligence supports operations across the city, bringing together datasets and encouraging data-sharing with other organisations. Milton Keynes authorities mentioned that the city already have significant volumes of

real-time data streams from city infrastructures, sensor networks, satellite data sources and social media, and other datasets collected through the MK:Data Hub. Their main focus was on enabling organisations to share data, and addressing barriers, such as data ownership, bureaucracy and governance issues. Peterborough authorities have also established mechanisms for feeding some data collected through their city projects to the Council's Central Intelligence Unit.

Several cities had established city performance dashboards with data feeds, although this has not been applied to smart city reporting. Manchester authorities were questioning whether dashboards were needed; and if so, which dashboard designs were best and whether a data-driven focus is adequate to create value for cities:

> City dashboards need to be well thought through for reporting on smart cities to be of real value… A number of cities are developing dashboards for reporting on smart cities, but I question whether the data behind the dashboard is giving the full picture?… To say you can feed it all into a dashboard is questionable. It's the trendy thing to do.

Bristol authorities stressed that smart cities is less about cities being digital, and more about cities being liveable, and achieving quality of life outcomes for citizens. Both Peterborough and Bristol city authorities were keen to collect both qualitative data and quantitative data to evaluate smart city outcomes, particularly for citizens. Rather than over-focusing on city data, dashboards and performance, several of the cities preferred to focus more on information, narrative and vision, in their thinking about smart cities as liveable rather than digital cities.

A focus for city authorities is to identify particular areas of governance where smart city data intelligence can be used effectively in the city. Bristol city authorities identified the importance of opening up data '…to unlock new opportunities, knowledge and information about the city', and were for example, using real-time

traffic data collected through the Traffic Control Centre to measure congestion in the city, combined with data from the Bristol Open Data Portal. Manchester authorities described, for example, the way data collected through their smart city work has been informing city strategies, such as climate change, economic development and transport strategies. Hence, the potential to capitalise on smart data intelligence is beginning to be realised.

City reporting processes

All the cities have established processes for reporting on city performance related to measuring progress on city objectives, set out in the Community Strategies (which some larger UK cities have), or the city's Council Plan or Corporate Plans, led by the relevant Local Authority. The larger cities including Birmingham, Bristol and Manchester also publish 'Annual State of the City Reports'. However, the cities acknowledged that their smart city work did not currently feed directly into the city performance reporting process to address statutory reporting obligations; and was therefore not subject to a formal political reporting process. This raises questions about how reporting on smart city work should be conducted –by whom, for whom and for which purposes.

Whilst the cities had established a variety of formal and informal city reporting mechanisms, most formal reporting on smart city work has been driven by the funding bodies. Projects were typically funded by consortiums and business interests outside the council (not by taxpayers) which reduced the need to report through city reporting processes, raising accountability issues. Milton Keynes authorities said '…The primary accountability for most of these projects is up through the funders, which is not the Council'.

The cities were interested in developing appropriate reporting structures that engage and empower stakeholders and citizens with their smart city work, through informal and formal reporting mechanisms, as well as supporting city learning amongst key actors across smart cities. Birmingham's Smart City Commission required quarterly reports, whereas Peterborough and Bristol used various informal reporting mechanisms through public forums and open stakeholder meetings for sharing ideas, criticism and progress. Milton Keynes authorities were considering whether to establish new reporting mechanisms, such as an annual report to city stakeholders and politicians on the overall outcomes of their Future City Programme.

City councils typically report on hundreds of KPIs as part of formal city performance, and many reported indicators have links to areas of smart city work i.e. energy, climate change, transport, waste and the liveability of the city. Rather than adding new specific smart KPIs to the city reporting process, which is an option for cities, the Bristol authorities suggested that a reporting mechanism was needed to show how smart city technologies and data contribute to the existing city KPIs and formal city reporting processes.

Influence on city decisions

All the cities thought their smart city programmes were beginning to have some influence on decision-making in the city, particularly associated with city investment and urban development. This included the smart development work around Manchester airport; the Bristol Energy Company (bristol-energy.co.uk/) that was intended to be '…smart from the start'; and Peterborough's Smart City Leadership event for public and private sector organisations working across city areas. The cities believed their smart city work was having a positive impact on the city, and expected this to continue with projects, such as Manchester's European-funded Triangulum project. Moreover,

cities identified the importance of learning from other cities in developing their approach to smart city development and evaluation, and were already participating in a range of European and UK projects on smart city measurement and evaluation.

Summary and Discussion

This case-study analysis informs understanding of the smart city, as a city in transformation (Wiig and Wyly 2016) with attendant evaluation and reporting challenges. The cities under consideration in the case studies, like many smarter cities, are developing through innovative programmes and projects that are '... integrated awkwardly into existing configurations of urban governance and the built environment' (Shelton, Zook and Wiig 2015, 15). The city authority-led projects are typically developed with and through partnerships between government, industry, university and citizen groups; and implemented at different scales, thereby having differential impacts across the cities' planned spaces, citizens and activities (Shelton, Zook and Wiig 2015). A focus on securing investment/funding for smart innovation projects supports already observed trends towards corporate and entrepreneurial governance (Hollands 2014), and the emergence of external funders/investors driving the evaluation and reporting of smart city work.

Most of the cities were at the early stages with their smart city evaluation work, and identified challenges for evaluation and reporting at the project, programme and city levels, which centred on how to measure the causal impacts on city outcomes, and prove the value of project and programme interventions. The cities already had significant levels of project data, although faced challenges of deciding what to do with the data and which methodology to use to measure the impacts of smart city interventions. Reporting challenges centred on communications to city stakeholders about the value created, and demonstrations of how smart city work contributes to city

performance and statutory reporting obligations. The city authorities were beginning to develop the use of data intelligence to support evaluation and reporting processes, and were investigating the opportunities afforded by smart technologies.

The findings contribute to debates around whether standardised smart city indicators are needed for evaluation approaches. Some city authorities were concerned about the meaningfulness of the current work available on smart city models, measurement frameworks and indexes. Some were unconvinced that an overarching, standardised smart city framework is needed, as this would not be sufficiently relevant to each city's unique challenges. Whilst BSI states there is '…no one-size-fits-all' model for developing future smart cities (BSI 2014b, 3), a challenge is how to build on current methodologies to develop standardised evaluation frameworks that are relevant to different smart city projects and programmes, and to cities with different challenges and strategies.

A synthesis of the city authorities' recommendations suggests that the design of smart city evaluation should address validity, through supporting the city's future vision and strategic objectives, for example, a vision of smart cities as liveable cities rather than digital cities. Validity issues also address flexibility, relevance and adaptability to unique city challenges and circumstances; and appropriateness to the development maturity and scale of smart projects. The design should offer measurable indicators (both quantitative and qualitative) that reflect the multi-faceted nature of smart cities, rather than focus on arbitrary or easily-measured indicators; and build on city data intelligence and data-driven mechanisms. It should represent the complexity of city systems and project/programme interventions, and as also noted by the EIP-SCC (2013), be open to improvement and evolution. The design should also address

utility/value issues through helping cities to identify gaps and opportunities in their smart city work.

A recommendation is that evaluation approaches should be appropriate to the level of intervention at the smart project, programme and city level. At the project level, city authorities were positive about establishing baselines for monitoring and measuring progress over time against strategic targets to demonstrate the validity of a smart city innovation concept; and from this base, identify projects with the greatest city impacts and replication potential to city-scale. This follows BSI guidance on establishing baseline measures, then monitoring progress against the current system performance and the KPIs associated with success criteria, aligned with the targeted strategic outcomes (BSI 2014b). However, the use of standardised KPIs should also be appropriate to the development maturity of the project, and supportive of emergent innovation opportunities, avoiding a premature rush to a crushing judgement of nascent innovation concepts leading to funding termination. In the early stages, demonstration of the innovation concept validity through monitoring and measurement may be sufficient.

As well as establishing baseline measurements, an overall recommendation is to develop evaluation frameworks that map and integrate evaluations and KPIs of smart city developments at project, programme and city levels and at different scales, to determine the outcomes for cities. BSI's Smart City Framework offers guidance for the evaluation of projects/programmes against critical success factors across a framework of strategic, cross-city governance and benefits delivery factors (BSI 2014b, 46-49).

Developing the value of data intelligence through new city mechanisms would have a key role supporting integrated evaluation approaches. The findings identify requirements to address governance issues with data curation, provenance/ownership

and access to data sources (Moonen and Clark 2013). It is noteworthy that smart city indicator frameworks typically draw only on legacy datasets (Giffinger et al. 2007; Cohen 2014; Ericsson 2014). There are therefore opportunities to capitalise on smart city analytics and real- and near-real-time data sources.

However, the complexity of urban systems and subsystems raises significant challenges for the representation of interlinked and embedded systems of innovation, measurement indicators and governance (Arnold 2004; Holman 2009); and establishing proof of the value and impacts of smart city developments, irrespective of whether they are standardised or specially-designed smart city evaluation frameworks. Evolutionary-systemic perspectives in Science Technology Studies on the evaluation of innovation systems can inform holistic, multilevel approaches to evaluation (Arnold 2004; Edler et al. 2012) that addresses systems complexity (Arnold 2004; Holman 2009) and supports an evaluation of evaluations, combining multiple evaluations to inform high-level evaluations of urban development policies and strategies (Magro and Wilson 2013). Rather than establishing new smart city KPIs, some city authorities would prefer to measure the contribution of smart city projects and programmes developed at city-scale against existing KPIs aligned with city strategies to establish city-level impacts. Acknowledging this preference, this approach arguably abnegates the policy utility of smart KPIs, and the potential of indicators for transforming governance (Holman 2009).

Analysis of the SmartDframe study findings identifies further issues for developing smart city reporting practices. A surprising finding is that reporting of smart city work is not typically embedded in current city management structures and performance reporting processes. This is explained by the lack of statutory reporting obligations driving the evaluation and reporting, which is led instead by external funders/investors. Potential consequences include: the risks of creeping

disintermediation (Rabaria and Storpera 2015), whereby local governance has a reduced intermediary role between citizens and powerful actors leading smart city development; reduced accountability issues for city authorities towards citizens (Glasmeier and Christopherson 2015); and poor monitoring and feedback to city authorities on urban development decisions and actions.

A recommendation is to establish management structures so that smart city work is embedded in open city structures, to support reporting through the wider community partnership of *all* the organisations responsible for the delivery of city strategies and plans around smart city outcomes, across the government, industry, university and citizen groups representing the key helices/actors developing smarter cities (Lombardi et al. 2012); and to establish formal reporting processes using data intelligence and standardised KPIs to reveal the contribution of smart city work to city performance and statutory reporting obligations. Integrated reporting methods can contribute to holistic reporting and analysis of the value, benefits or 'stock of capitals' being created by smart city programmes through a process of integrating measures with connected information flows (IIRC 2013), which is of relevance to reporting on the delivery of smart city benefits (BSI 2014b).

In conclusion, without effective evaluation and reporting processes, it is difficult to determine how and whether smart city developments effectively address 'wicked' urban problems (Hollands 2014; Goodspeed 2014), and identify the value, outcomes and impacts for cities and citizens. The case studies of the UK cities under consideration show that smart city evaluation and reporting is in early stages of development, and only beginning to contribute to governance and urban development decisions. However, the findings contribute to debates around: whether standardised smart urban indicators can be scientifically developed to be meaningful, valid and relevant to complex cities

and support micro-level smart city innovation projects and programmes and city-level developments; and how to design indicators that have value across levels and scales of smart city interventions, and processes of evaluation and reporting. Whilst there are numerous challenges ahead, on balance standardised indicators arguably offer distinctive value, including utility for governance and policy processes through capitalising on big data intelligence.

Next steps are to support a research and development agenda with cities and regions, to build on the recommendations to support appropriate and effective evaluation and reporting of smart city innovation projects and programmes. Further research will help evidence the value of smart city developments and provide important feedback to shape the next phases in developing future cities.

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