Information management in the smart city

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Introduction

The concept of the "Smart City' is frequently referenced in academic research, in grey literature and government reports, but often interpreted inconsistently. A great deal of progress has been made in the last decade, with many cities across the world deploying technologies such as traffic management. However, while developments in information management are central to smartening of cities, there is no agreed framework by which to assess the progress of smartening of a city in relation to information management. In this paper we review how information management contributes to smartening of cities and suggest a framework for managers and city planners to use in planning and implementing city smartening and measuring progress, and for researchers to use in building their conceptual frameworks. We also consider the choices facing those responsible for or involved in city-smartening, in terms of business models and centralisation or decentralisation of information management initiatives.

Most city smartening projects involve transforming an existing ecosystem, namely a city, its transport and various other city attributes, mainly by deployment of information management in as pervasive and real-time a form as possible, rather than by radical change, in which the activities and players change. As experience with city smartening evolves, and as technology evolves, the prospect of more fundamental transformation opens up, with new players emerging, existing players changing what they do and when they do it, and new relationships developing between players. These developments will all have significant information management implications.

Definition of smart city

Due to the rapid evolution of thinking about smart cities, there is no consensus on the definition of "smart city". Deakin and Al Waer (2011) suggest that a smart city is defined by its applications of many kinds of electronic and digital technologies to transform life and working environments in a city, including via embedding the technologies in public systems, combined with a consciousness of all players in the city that they live and work in a smart city and that its "smartness" benefits them. Other definitions (e.g. Caragliu et al., 2009) highlight the focus on quality of life, sustainability and engagement of the population and organizations. Where most writers agree is that smartening of a city involves changes to energy management, building design and management, mobility services and practices, infrastructure development and use, healthcare design and management, technology implementation and governance and citizen knowledge and behaviour. Given the rate of evolution of relevant technologies, the smart city is best considered not as an end-point but an unending process.

The analyst firm IDC (2018a) proposes that the concept of "Smart Cities" is a "construct in which to frame local government transformation", with the motive for local governments being to "transform in order to develop sustainably, improve resilience, meet citizens' rising expectations, and attract investment, new businesses, and talent". In other words, the focus is on what public authorities must do to smarten their cities. IDC (2018b) identifies that most spending for the near future will focus on intelligent transportation, data-driven public safety, resilient energy and infrastructure, visual surveillance, smart outdoor lighting and environmental monitoring.

While the IDC definition captures the direction of most smart city initiatives, it does not include the efforts made by the other players – whether organisations or individuals – involved. As we shall see, it is the co-operation between local (and central government) and a wide variety of organisations and individuals that may hold the key to smartening cities. We agree with IDC that a critical element is the effecting of behaviour change amongst all players. However, the focus of IDC's work, which includes a smart city competition, is on identifying tens of use cases for smart city projects (and so implicitly for local government initiatives) and the information technologies that will support them. IDC suggests that these use cases will support five strategic priorities: economic development and civic engagement, sustainable urban planning and administration, data-driven public safety, intelligent transportation, and resilient energy and infrastructure.

Much smart-city research focuses on the information technologies that transform a city from being *dumb* to *smart*. The technologies include big data (Wright et al., 2018), artificial intelligence, analytics, as well as new ways of collecting and transmitting data – the latter particularly important for enabling smart city participants to keep in touch with the smart city and the smart city to keep in touch with them, their activities and needs. They include sensors, mobile and wireless devices, including innovative use of voice and displays. A key aspect of smart city thinking is the requirement for openness of data, usually through an open data platform, such as London's Open Data Store (Stone and Aravopoulou, 2018), to support planning, operational management and citizen engagement. One characteristic of a smart city is that it is a digital city, defined by Yovanof and Hazapis (2009) as a connected community that uses open digital standards and innovative services to meet the needs of governments, their employees, citizens and businesses, and in which citizens are interconnected and share information easily. Smartening a city may enable citizens to carry out their existing activities much more efficiently, with less stress, but some researchers e.g. Komninos and Sefertzi (2008), focus on how smartening a city can transform the daily life of those in it.

Many city leaders have announced smartening plans, to cut congestion, remove environmental threats, shift demand to off-peak periods, encourage sharing, make journeys easier for users and more effective or profitable for transport suppliers, and encourage employers to ease congestion by being flexible about hours of work or working from home (IDC, 2018a). Government support for making cities smarter, easier to live in, and more environmental is strong. However, ambitions may clash with the realities of demographic change, regulatory complexity, business demands and budgetary constraints. While some forward-thinking employers are offering flexible hours and work locations, many companies and public-sector organisations are committed to fixed hours of work/operations, creating high peak loads and congestion (Korosec, 2018). This is partly because when income rises, the demand for mobility rises faster, and when the price of mobility rises, most are prepared to pay (Dunkerley et al., 2014). Although as work in big cities become increasingly services work, with fewer workers and managers sealed up in factories and offices all day, allowing increased flexibility in travel-to-work times, workers may not travel less overall, but may drive more - to local hotels for meetings, on the school run, to shops or to evening meetings. So, when regulators try to penalise mobility, demand stays.

Nonetheless, much progress has been made, best demonstrated by the winners of the IDC Smart City Awards for the US (IDC, 2018c). Cities such as London, Singapore, Barcelona and Bristol are cited as being most advanced (Lofthouse, 2018; The Institute of Engineering and Technology, 2018). However, progress usually relates to what suppliers and cities are doing to handle the demand from the mass of travellers – see for example the US winner in the civic engagement category, Kansas City (AWS, 2018). There is little evidence of approaches where individual travellers are an integral part of the optimization.

Smart city innovation, platforms and ecosystems

Many innovations involving final consumers are enabled by transformative innovations higher up the value chain. Significant recent examples of this involve new information platforms, where one or more organizations create a platform with which other companies and organizations engage, to change how they manage delivery of benefits to the ecosystem in which they work. For such transformations to be successful, several conditions must hold, as follows:

- A supporting ecosystem must arise to facilitate the new approach (Stone, 2014a). This often involves the creation of new business models (Stott et al., 2016) and in some cases, moves by companies engaged in related activities into the area.
- Ecosystem firms must invest in systems and skills, so that they can deliver (Stone, 2014b).
- The transformation must offer an effective way of achieving objectives for different stakeholders
- Customers for the ecosystem must not only learn how to use and then respond to the approach in sufficient volumes, generating sufficient value for stakeholders, but also to innovate themselves and

become smarter in how they approach use of smart information to manage their lives as workers, consumers and travellers.

The transport industry has a strong appetite for embracing innovation, in areas such as automation, self-service and journey planning support. The airline industry has been among the leaders in all parts of the value chain, from airliner scheduling to sales. Some airlines use "dynamic pricing" on their websites and even "surge" pricing according to short-term demand (like the model Uber uses to charge more for rides in the rain or at rush hour). Technological progress has opened up a world of optimized journeys, of cars running on batteries and fuel cells, of driverless vehicles and trains, of sharing of vehicles (with or without drivers) and shared scooters and bikes, of digitally-driven transport management.

On more advanced city public transport networks, users access transport information mainly via their mobile phones. Cloud platforms and open data approaches have allowed travellers to find ways to optimize any journey on a wide range of dimensions (time, cost, comfort, accessibility etc.). Transport providers, whether of mobility services or of the infrastructure to support them, are improving operational efficiency and profitability through collection, analysis and sharing of transport-related data, hosted in the cloud and available to app developers (Stone and Aravopoulou, 2018). Sensors such as GPS, gyroscopes, microphones, cameras and accelerometers, are commonplace, whether in smart phones or transport assets. Their ubiquitous deployment is accompanied by software programmes, for management, control, analytics and data collection (Bhoraskar et al., 2012; Nemati et al., 2017; Pires et al., 2016).

The change in consumer culture and its effect

A factor supporting city smartening is a change in consumer culture towards digital living (Ashman et al., 2015). This, combined with and partly caused by the rise of many large (e.g. Amazon) and small online suppliers, and the switch to online selling by many established retailers and other product and service suppliers, has transformed or is transforming marketing and indeed whole industries. These include financial services (Stone and Laughlin, 2016), utilities (Stone and Ozimek, 2010), travel and transport (Stone and Aravopoulou, 2018), media and telecommunications (Stone, 2015) and many others, as well as leading to the demise or drastic down-sizing of many existing players or their absorption into other firms. The use of the customer data arising from this marketing transformation has changed the way customer information is used to drive marketing strategy (Stone and Woodcock, 2014; Woodcock and Stone, 2013). This transformation is a critical enabler of the smart city. Without it, many aspirations of local authorities to smarten their cities would be unrealistic. Citizens are generally used to giving high volumes of data, and using data provided by others, in their daily lives, and understand the importance of acquiring and learning how to use the many technologies that enable them to do this, particularly smart phones and broadband. For example. CompTIA reported from a survey of 1000 US households that 6 in 10 American citizens are hoping to be a 'smart city resident' (Smart Cities World, 2018).

In an era where more comprehensive data protections provision (e.g. General Data Protection Regulation, or GDPR) are being established, one limitation to city smartening relates to citizens' willingness to give the data needed (Finch and Tene, 2018; Kitchin, 2015; Taylor et al., 2016). If a customer does not wish to provide data (e.g. about their location or travel plans), the smartness of the city will be limited, as will the citizen's own quality of service from the smart city. For example, if a citizen is not happy to give data on travel plans, then they cannot be warned of when their plans are likely to be infeasible. Of course, they will as with any innovation need to go through a learning curve, and while early adopters may lead the way, being prepared to give data in exchange for improved planning information, others may take time to follow. Because the smart city is not a single innovation, and in many cases not presented to consumers as such, it is not easy to carry out studies on the acceptability of such innovations, although Transport for London's study of the value of open travel data is a good example of what can be achieved (Stone and Aravopoulou, 2018).

Demographic factors may also have an influence. For example, PEW research indicated that lower income Americans typically lag in technology adoption (Anderson, 2018). A smart city ecosystem relies partly on the ownership of personal devices, whose diffusion is partly affected by affordability of the device.

For a smart city to work, providers of products, media content, infrastructure and transport equipment need to create more open applications which can interact with the many other smart products and services that are used in the day-to-day life of citizens. Citizens cannot be expected to stick to a single ecosystem. Open

API protocols that allow applications and systems to link to each other will make it more likely that a given information source will be incorporated into the citizen's personal ecosystem.

However, the above changes have had some negative effects, for example, the rise in congestion caused by home delivery (Visser et al., 2014; Pålsson et al., 2017; Goodchild and Toy, 2017). Bouton et al. (2018) estimates that this can account for up to 2-4% of a cities GDP. However, delivery to private addresses might be at an early stage of evolution. For example, the delivery of goods to cars is a recent phenomenon where parcels are placed in the car trunk of a connected (smart) car and remotely unlocked/locked by the driver via a pre-authenticated digital key provided by the parcel's owner (Arthur, 2016). This allows delivery organisations to deliver outside usual operating hours (night-time deliveries) or ensure that repeat routing is not required with more parcels being securely delivered each time. Amazon's experiments with drone delivery fit into the same category of attempts to smart the e-commerce delivery system.

Platforms, big data and the cloud

Platforms rely on the ability of users (whether business or individuals) to create, access and analyse very large amounts of data (or "big data") on a variety of devices, including ones which form part of the "Internet of Things" e.g. sensors. The rise of cloud computing (use of a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local computer) has stimulated platform development, allowing data-intense platforms to support the delivery of better customer experience and service (Stone et al., 2017). The rise of platforms is driven by several transformative digital technologies. Social networks connect people globally and allow them to maintain their identity online (Woodcock and Stone, 2013). Mobile technology allows connection to this global infrastructure anytime, anywhere. "Big data" allows collection, storage and use of massive volumes of data (Wright et al., 2018). Rapid progress in analytics and artificial intelligence have increased our ability to analyse these much greater data volumes.

The availability of third-party cloud capacity has facilitated use of platforms where usage fluctuates greatly. This accounts for the rise of new cloud computing suppliers such as Amazon Web Services (2018), as well as cloud storage provision by existing suppliers such as IBM and Microsoft (Wright et al., 2018). This is a critical requirement for a smart city, where information processing loads fluctuate dramatically. Peak hour travel generates high volumes of data, whether in movements of citizens or transport assets, or in enquiries about the performance of the assets (e.g. whether trains or buses are on time). Energy usage peaks in the morning and evening, while leisure and entertainment use peaks in the evening.

The discovery that platforms can transform an industry and create new profit opportunities has led to:

- Emergence of firms whose main business aim is the creation and commercial exploitation of a platform (Stone et al., 2017).
- Development of platform services by existing players, such as those cited in the previous paragraph.

Many smart city innovations are based on platforms, whether they are used to support interactions between organisations and citizens, or between the many organisations involved in smartening cities.

The real-time city and big data

Hashem et al. (2016) overview the expansion of big data and the evolution of Internet of Things (IoT) technologies that play a crucial role in smart city initiatives, allowing valuable insights to be derived from data from a variety of sources, sensors and devices. Townsend (2013) proposed that the emergence of 'big urban data' produced by smart cities could offer significant opportunity for real-time analysis of city life that can offers insights that can enhance everyday living and transport decision-making, and empower an alternative vision for city development, creating a new mode of urban governance, and well as potentially providing the 'raw material' for delivery of more panoptic view of a city – one that is more 'efficient, sustainable, competitive, productive, open and transparent'. Townsend also warns of the politics and possible corporatisation of smart city governance and the use of technological lock-ins, plus the risk of creating more hackable cities. Al Nuaimi et al. (2015) note that a variety of beneficial application domains, for the smart city can be realised provided challenges around security are resolved, and rigorous design and development models and methodologies are used. They also link this to the need for highly trained human resources, the need for support by the governing entities. Cheng et al. (2015) present an architecture overview of a working big data platform which has been deployed and integrated with SmartSantander

(SmartSantander, 2018), one of the largest smart city testbeds in Europe, to collect city data and then serve results to a few real-time applications, and conclude that while many of its components can assist in offering timely and valuable inputs for smart city data platform designers to consider, it highlights the need to enhance the support of semantic data, to develop a better sharing of knowledge between different applications, and improved data security and system security.

The changing nature of mobility

The growth of high speed, low cost delivery services and low cost, on-demand ride-hailing services has a significant impact, sometimes negative, sometimes positive, on city congestion and mobility (Qi et al., 2018). However, the data associated with these and other technologies can provide insights that enable regulators and operators to manage mobility services better and create transportation or logistics networks that serves users' needs better and in a more integrated way. They also allow customers/travellers to reduce time spent travelling or to avoid unnecessary travel altogether. This is important in cities such as London, where the population is growing faster than the additional capacity being provided in public transport systems.

Supplier or customer orientation in smart city development

In much mobility and smart city thinking, the main focus is the perspectives of city managers, public and private transport providers, and technology suppliers, to maximize the efficiency of the urban transport system by discouraging unnecessary private vehicle use and promoting more effective, healthy and environmental modes of transport, combining 'push' mechanisms to reduce use of cars (e.g. parking space restrictions, congestion charging) with the 'pull' of improved public transport service (more passenger-friendly stops, bike and ride, better walking routes). However, some initiatives, using the label "active travel management or active travel demand management", are starting to focus on the customer – the travellers and citizens themselves (Hu et al., 2015; Ferguson, 2018; Petrunoff et al., 2016).

The concept of incentivising behaviour through offering prizes (Merugu et al., 2009) has generally shown to be more effective if a small number of large awards are offered frequently rather than small prize awards. A trial was conducted by INFOSYS Technologies in Bangalore, India, in which commuters that took a bus during less congested periods (where there was more bus capacity) received credits, with commuters grouped based on their credit amount. The travellers changing their behaviour most significantly were entered into a prize draw for the highest amount of money, with other groups tied into four sets of rewards of declining value based on their evidence of behaviour change. The Bangalore trial led to a doubling of travel from staff during less congested periods and a 24% decrease in overall average travel time for all bus commuters within the firm, a change so significant that Infosys could remove several buses from service, with the cost savings of doing so more than covering the cost of providing the incentives (Merugu et al., 2009).

Barlow (2017) confirms that smart city initiatives tend to focus on the tangible benefits of lowering the high public costs of running a city, improving efficiency and reducing expenditures, while technology firms focus on combining advanced computer technologies, sensors, high-speed data networks, predictive analytics, big data, and the Internet of Things. The result is solving one problem at a time, so services are vertically integrated but not horizontally integrated, provided more intelligently, but not making the city a better place to live. Part of the problem is focus on technology enablement rather than involving the citizen as an equal partner – especially when the citizen is also a key creator of data. However, there may be a consensus emerging among technology providers on this point. For example, IDC in conjunction with Microsoft (Clarke, 2017) confirmed that connecting systems and siloes is key to delivering an 'outcome' based digital transformation to address the challenges of the competition for talent, business investment, rapidly growing and aging populations, climate change and economic inequality and the digital divide. Carke suggests starting with smaller, focused, department-level projects and growing, step by step, to a unified city ecosystem with a clear set of priorities having been defined.

Partnership

Partnership is key to solving the challenge of delivering an integrated smart city, as no single vendor offersing a true end-to-end solution that can effectively cover devices, connectivity, data, apps, and app development (Clarke, 2017). It proposes that cities should instead look to vendors who can help provide users with flexibility and customisation through their ecosystem. McKinsey (2018) notes that while good management is central to smart cities, governments cannot manage all aspects of the ecosystem themselves, as private companies and residents play an active role in shaping a city's performance, while many smart city innovations are revenue-producing ventures from private sector companies.

Mobility as a service

Mobility as a service aims to manage transport demand in a society that increasingly consumes products and services on an on-demand basis rather than "committed acquisition" basis (European Platform of Mobility Management, 2017). For example, instead of buying a bicycle, one can be hired by the hour or shared. Instead of buying or leasing a van, one can also be rented by the hour. Pooling or sharing becomes viable. This applies in many service areas. For example, instead of subscribing to a TV channel for a long period, a subscription can be bought for a day. In transport, travellers become fertile data producers, as knowledge of their patterns of requests and actual use can be used to develop new services. For the approach to work. In transport, bookings and payments need to be managed collectively, combining services from public and private transport providers in a unified gateway that creates and manages the trip, which users can pay for with a single account, with a fully integrated ticketing or charging system across all transport modes, requiring management of levels of service, financing of infrastructure, and coordination across all provider organisations. However, there is a 'trade-off' between maximizing individuals' freedom to 'travel' and the efficient operation of the transport system, while to work efficiently. Put simply, 30 smart or possibly driverless cars or a similar number of shared bicycles can create much more congestion than a bus.

An example of customer-focused mobility management

Consider a hypothetical example. Suppose all potential users and suppliers of transport in a city are represented on an information platform designed not just to solve the problem of the individual traveller but to meet the needs of the whole city. It allows users to register their interest in making a journey or series of journeys, at particular times, their reasons for making a journey (commuting, business meeting, leisure experience etc.), their requirements for speed and other journey attributes (e.g. privacy, ability to work on a device, use a phone, travel with someone), their willingness to pay, their flexibility concerning timing and other attributes of trips, and other attributes of their demand.

Suppliers of different transport modes and facilities register the availability, costs and other attributes of different transport modes and capacities and continue to update this by sensors of various kinds. Employers input their requirements and flexibilities, taking into account their need to demonstrate their attractiveness as an attractive employer in the competitive search for talent. Parameters are set to allow the system to optimize in different ways (costs, environmental, essential workers, etc.).

Consider a possible commuter journey that might take place within this framework. A group of commuters who have categorized themselves as being flexible (either in general or for a particular day/week) is told to delay their journey into work by an hour and use different routes and/or modes – the group being them and their work colleagues. Their employer is happy because they have allowed this, because their workers arrive fresher and more productive, having already achieved more because they took less time on their journey or could work in public transport because they did not have to stand or wait, get frustrated, and avoided being crushed in a crowded rail coach or bus. The commuters pay less for this journey, which is more comfortable than it would otherwise have been. Late workers might be given priority to ensure an even faster journey to/from work, and might even get some loyalty bonus. Alternatively, an employee might be informed the night before that they should leave very early, so that they can start work early and get home early. Or they might be told to work from home that day, with work being rescheduled to enable them to work on projects best suited to home-working. Productivity would increase greatly as a new and flexible way of working is introduced.

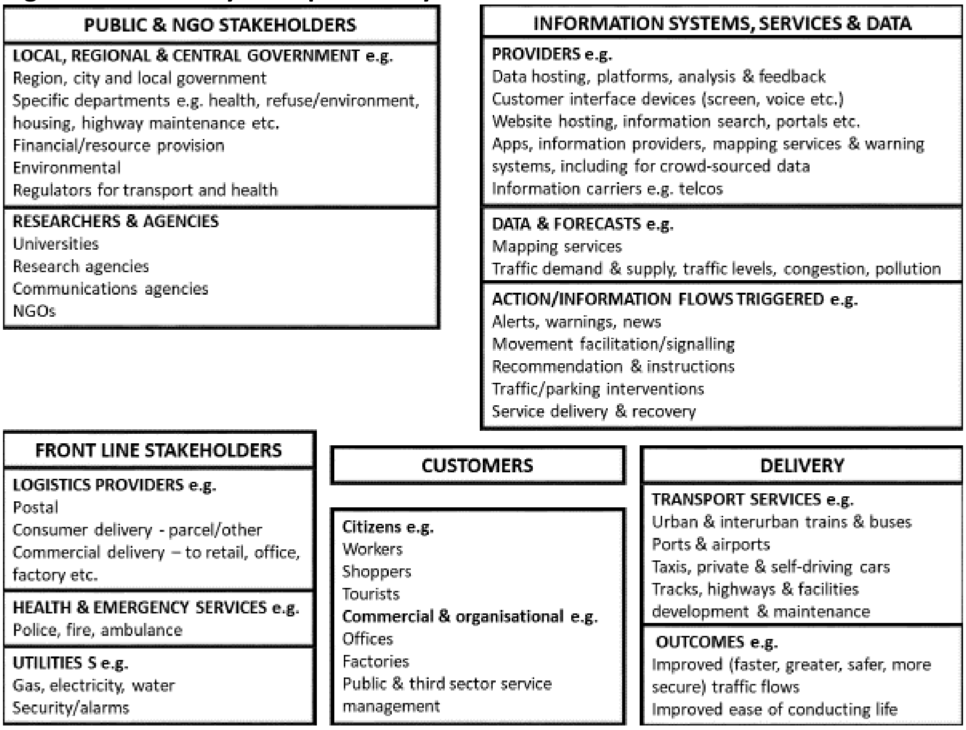
Similar scenarios could be identified for every journey type of individuals – business meeting, shopping, leisure, emergency service, school run, etc. etc., and for logistics and deliveries. Priority and discount pricing for particular choices could be the basis for incentives, as well as more sophisticated nudging of behaviour relating to congestion, air quality or operational needs (Gandy and Nemorin, 2018). Location plans and planning permissions would use these ideas strategically, and planning permissions might be made conditional of employers accepting certain kinds of flexibility. Of course, such a system would need to be ethical and manage securely personally identifiable information associated with mobility.

Most of the technology for the above exists (Balakrishna, 2012), in the database systems/platforms, publicly available APIs, 5G networks, wearable devices, sensors, artificial intelligence, apps, messaging devices and so on that we all use partially. However, as we have seen, each supplier tends to focus on their own operations, not on how the whole system could work to everyone's advantage. One way to deal with this is for service operators to be contractually obliged to submit data to enable better system-wide optimization, wherever in the ecosystem of suppliers the data comes from - transport and infrastructure providers, systems, apps, data, communications, sensors, chargers, users and their equipment, etc. etc. This would help them run a more efficient service and lead to a more effective transportation network.

The ecosystem

The smart city transport ecosystem can be depicted as in Figure 1.

Figure 1: Smart city transport ecosystem



Source: Authors

The result of smartening a city is to create information flows *between* most of the players in the ecosystem, and to increase the focus on the quality (e.g. comprehensiveness, reliability, speed of update, ease of access) of information *within* each player. The most important flows are between the three groups at the bottom of the diagram, supported by the activities in the top right of the diagram.

The other change which takes place with smartening is the introduction of platforms which host data arising from the different participants. At the top right-hand side, providers of information systems, services and data, may develop from hosting for individual organisations to a situation where data is opened and shared between several organisations, such as in London's Open Data store. However, these platforms may also be created by independent aggregators, such as CityMapper (CityMapper, 2018), who may in turn integrate forward into the provision of service (Stone and Aravopoulou, 2018).

Flows of data in the smart city

A key characteristic of smart city evolution is the rapid growth in the depth, breadth, frequency, volume, quality, reliability and accuracy of data flows, not just between public authorities and others, but between all the players. Just as importantly is the integration of data from many different sources so that players making decisions can see all the data they need. A good example of this is the Santander smart city initiative in Barcelona involving combining many data sources on one platform on which individuals can access and analyse the data (Barcelona Ciutat Digital, 2018). The SmartSantander augmented reality application uses open municipal data to provide information on mobility (traffic and public transport) and weather to users at many points, such as beaches, parks, gardens, points of interest, and shops. The London City Dashboard provides similar information, including public transport status, weather, air pollution, news updates and traffic cameras (City Dashboard, 2018). The Centro De Operacoes Prefeitura Do Rio in Rio de Janeiro, Brazil brings together data from surveillance and analytics, including data from 30 different agencies, from traffic to crowdsourced user data where algorithms and analysts process this in real time (COR, 2018).

Such systems encourage data providers to make their data available and encourage citizens and others to use the data. As the smartness of a city increases, more analysis can be carried out on the use of data, allowing data providers to identify which information is most useful and what gaps there are. Much of the information is provided by sensors distributed around the city, and as their number increases, more data becomes available on, for example, traffic status, parking availability or queues). If these sensors are primed to collect data frequently, or even constantly, the accuracy and reliability of the information improves. In the case of mobility, a sensor on each connected car, giving data on location, speed and local traffic conditions, can allow traffic planners to monitor congestion and as a result update information to other drivers in order to ease that congestion. However, as applications like Waze (Amin-Naseri et al., 2018) and the example from Rio de Janeiro above show, this information may be provided on a crowd-sourced basis, without public authority involvement (Batty et al., 2012; Jin et al., 2014; Farkas et al., 2015; Zook, 2017).

Smart City Grading

As cities become smarter, city planners and government need planning tools to help them define their strategy and map their progress, and to assess their project progress, while private sector participants need to be able to assess commercial opportunities. We therefore propose a Smart City Information Management Model (Figure 2), adapting the smart product and service model of Porter and Hepplemann (2014). It suggests how smartening of a city progresses through improved information management. As with all such models, there is simplification, with characteristics at each stage being suggestions rather than absolute criteria, but experience in other areas demonstrates the value of such an approach (Parnell et al., 2018), in terms of giving a sense of current progress and remaining targets.

Figure 2: Smart City Information Management Model

	Characteristics
Dumb	Several information networks exist, but they are not interconnected. Many stand- alone sensing and information access devices in use, feeding into or taking data from individual networks. Assets such as cars, buses and trains may have basic sensing devices, but these are used only by their own drivers or within their own networks with no networking devices make up these 'dumb' assets.
Awakening	Most important devices and assets are connected to a system, but systems are disparate and not connected with each other. Ecosystems (including app development) are evolving around the databases/platforms that support individual uses/applications e.g. rail transport, taxis, buses, parking, but they are not connected or at most connected to a subset of other ecosystems. Some data is being communicated between certain devices.
Smart connected asset	Assets and individuals are connected with each other over some sort of network and can be accessed from a wide range of devices, but connections are not always automated and may fail, and usability is an issue. Platforms and aggregators have emerged and are competing with each other to secure connection of individual, organisations and assets, by providing appropriate incentives, whether financial or service related.
Connected systems	All relevant assets and individuals are connected with each other through a variety of different systems, which members of the ecosystem can choose between.
System of systems	Aggregators now connect all systems at a meta-system level, but there may be more than one of these meta-systems Apps have emerged to allow use of these The meta-system may not be owned and/or managed by the city authorities

Source: Authors

The model examines individual assets and ecosystem members, showing the stage that a particular city has reached. It can be used to identify which information management changes are needed to smarten the city further, identify where new datasets are needed, and perhaps how the data should be collected, stored and used.

One contentious point is whether the final outcome will be developed, sponsored and/or controlled by the city, or by third parties, perhaps commercial members of the ecosystem. Here, a lesson can be drawn from the business model literature (Stott et al., 2015), by asking the question, what is the business model of the city or of the city's public transport authority. For example, Transport for London runs several different business models, as provider (underground rail services), contract manager (buses), regulator (taxis), road network maintainer) for some roads), road quality auditor (for other roads maintained by central government) (Stone and Aravopoulou, 2018). In an age when much platform innovation is undertaken by the private sector, to the benefits of many private users, whether consumers or businesses (Wright et al., 2018), it can be argued that there is no reason why smartening of a city should be premised on monopolisation of the information management aspects by city authorities, particularly given well-documented problems with public sector innovation and what seems to be the relative success of collaborative, participative and bottom-up approaches and (De Vries et al., 2016; Arundel et al., 2015; Balfour et al., 2017; Torfing, 2018). As the experience of Transport for London has shown (Stone and Aravopoulou, 2018; Wright et al., 2018), an open, sharing approach, with competition amongst providers of a wide range of information management services, may be the best approach, with the key role of the city authority being a regulator and standards-setter. In particular, it seems important to establish open Application Programming Interfaces (APIs - functions and procedures that permit creation of applications that access the features or data of an operating system, application, or other service), as in London and Barcelona (Namiot and Sneps-Sneppe, 2014).

Conclusions and implications

This research identifies that developments at the leading edge of information management as applied to smart cities and their public and private stakeholders may lead to developments which are either convergent, on a publicly specified and possibly publicly owned data platforms, or divergent – with the emergence of different platforms, whether public or private, whether complementary or competitive (Schaffers et al., 2011). In this respect, the evolution of smart city information platforms may mirror those of information platforms in other digital areas, such as home shopping, insurance or media.

For those involved with the promotion, development or delivery of smart cities, the implications are clear – do not presume that the centralising, controlling approach often adopted by governments for information management approaches involving many ecosystem players will work better than a more liberal, enabling but regulating approach. For the providers of possible ecosystem platforms, the main implication relates to the need to focus on the benefits of all ecosystem players, particularly those who stand to benefit most from the smartening of a city, whether they be organisations or individuals, and to ensure that collaboration between all members of the ecosystem is established on a firm basis, with recognition that many players will need to forego prioritisation of their own interests, in order to focus on the needs of the smart end-user, whether they be citizens or organization. It is hoped that this paper will provide a firm basis for taking this kind of collaboration forward.

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