Chapter 8
Smart Cities: Concepts, Perceptions and Lessons for Planners

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Abstract What is a "smart" city? This paper examines concepts and perceptions of city officials from six "smart" cities, Boston, San Francisco, Amsterdam, Stockholm, Singapore and Rio de Janeiro. Their "smart" efforts, gathered through interviews and secondary sources, are analyzed against four theories of "smart" cities; (a) "smart machines" and informated organizations, (b) partnerships and collaboration, (c) learning and adaptation, and (d) investing for the future. The findings show that instead of converging toward a single definition of being "smart", the cities have taken different approaches in planning and implementation, and adopt different combinations of elements from the theories. The cities' experiences and elements of being "smart" are distilled and presented as learning points and pathways for other cities.

1 Introduction

The "smart city" buzzword is captivating city leaders and planners worldwide. It is commonly associated with the application of information and communications technologies (ICTs) to reap efficiencies and benefits. Yet, the definition of "smart" cities remains diverse; according to Caragliu et al. (2009), "a fuzzy concept". Will inadequate understanding result in cities making poor investments in technology and infrastructure? Vanolo (2013) argues that the lack of definition allows cities to use the buzzword to support their own agenda, and hence, any examination will need to be "contextualized and related to specific cases". In this vein, this chapter

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explores how city planners are conceptualizing "smart" cities and whether these concepts consistent with theories of being a "smart" city.

2 Methodology

The concepts and perceptions of officials from six "smart" cities—Boston, San Francisco, Amsterdam, Stockholm, Singapore and Rio de Janeiro—were examined. Data was collected through phone and email interviews, and secondary sources (e.g. news articles, blogs, city reports, etc.). Cities' efforts were analyzed against four theories of "smart" cities; (a) "smart machines" and informated organizations, (b) engaging communities, technology providers and research institutions, (c) learning and adaptation, and (d) investing for the future. As the cities differ in size, mode of governance, planning and management, their approaches were examined in light of their own contexts. Their experiences and elements of being "smart" were synthesized and distilled to draw several learning points and conclusions.

3 A Brief Survey of "Smart" Cities and Technology Providers

Surveys of "smart" cities show that notions of being "smart" vary. Neirotti et al. (2014) analyzed from seventy cities that "smart" concepts are applied in diverse domains—"hard" (e.g. transportation, energy and resource management), "soft" (e.g. education, innovation, social inclusion) and "in between" (e.g. healthcare, public safety)—and concluded that there is no unique definition of "smart" cities. Similarly, Ching (2013) observed from over fifty cities that initiatives are applied in different fields, with some cities having implemented them while others remain in a conceptual or development phase. Batty et al. (2012) categorize cities' efforts into those which are "badging" or "regenerating" themselves as "smart", the development of technopoles, and the application of ICTs in urban services, urban intelligent functions, and online and mobile forms of participation. For their "smart" initiatives, many cities partner with firms providing expertise and technology, including IBM, CISCO and Siemens. The global market for investments in "smart" technology and infrastructure is projected to grow, exceeding $39 billion in 2016 (ABI Research 2012), and totaling $108 billion between 2010 and 2020 (Pike Research 2011). Multidisciplinary firms such as Arup provide consultancy services for cities on investments in "smart" initiatives.

4 Four Theories of "Smart" Cities

As an adjective, "smart" is associated with being clever and intelligent, possessing acumen, learning and being adept. In the context of modern technology, "smart" is associated with intelligent autonomy achieved through computer programming or guidance.[1] For cities, "smart" concepts can be grouped under four theories.

4.1 "Smart Machines" and Informated Organizations

Assumptions: The "smart" city uses ICTs for automation and intelligent functions, and structures processes, organization and governance to take advantage of the technologies.

In her theory of "smart machines", Zuboff (1988) highlighted *automation* as one of two dimensions in the application and impact of intelligent or information technology (IT) in workplaces. Automation breaks down human tasks, translating human actions into software instructions, i.e. information, that guides machines to perform tasks repeatedly and reliably. When city functions employ "smart machines", made intelligent through the use of data sensors and computing algorithms, they are envisaged to perform more efficiently, accurately and reliably than what could have been done by humans, if humans could perform such functions at all. For example, the Integrated Operations Center in Rio de Janeiro is made to predict the amount of rainfall more accurately than standard weather forecast systems and more efficiently alert city departments for flood mitigation operations (Singer 2012).

Zuboff's second dimension, *informating*, takes advantage of "smart machines" generating new digital information about underlying processes, creating potential for organizations to exploit and innovate their organizational structures and processes. Brynjolfsson and McAfee (2011) believe that humans and "smart machines" combined, through the re-engineering of processes to exploit ICTs, can improve business organizational models and reap benefits. Good organization, governance and management are also underscored as essential foundations for "smart" cities (Morier 2012; Belissent 2011). Most 'smart city' efforts involve some level of ICT-enabled automation, and many also claim some level of informating although significant achievement along this second dimension is much more elusive.

[1]Sources: Collins Dictionary, 2012, "Smart"; Merriam-Webster Dictionary, 2012, "Smart"; Merriam-Webster Learner's Dictionary, 2012, "Smart"; Oxford English Dictionary, 2012, "Smart, adj.".

4.2 Beyond "Smart Machines": Partnerships and Collaboration

Assumptions: The "smart" city involves partnerships and collaborations between city governments, communities, businesses, research institutions, etc. *within a framework that drives innovation.*

Other theorists view "smart" cities beyond "smart machine" analogies, shifting the focus from city functions to governance, especially from a liberal democratic perspective (Allwinkle and Cruickshank 2011). For example, Hollands (2008) adopts a critical view on self-proclaiming "smart" cities, highlighting that the use of ICTs is limited in the transformative capacity of cities without integrating human capital and shifts in the balance of power between government, businesses and communities. Haque (2012) critiques that 'smart' strategies should focus not on "the city as a single entity" but rather on 'the smartness of its citizens', who are idea generators rather than recipients. Townsend (2013) proposes the vision for "smart" cities to involve more social and inclusive processes of grassroots innovation. The social perspective is echoed in terms of empowering citizens without excessive emphasis on being a "machine city" (Sennett 2012) or "shallow" technical optimization (Greenfield 2013), and seeing "smart" efforts as a sociotechnical approach to solving urban wicked problems through collaborative planning (Goodspeed 2015). Hoornweg (2011) stresses that "smart" cities "ensure good communication between government and citizens", and "use all the local resources available in decision making and service delivery, e.g. universities, senior citizens, business community", thus underlining the need for cities to engage their communities and local organizations.

4.3 Learning, Relearning and Adapting

Assumptions: The "smart" city learns, relearns and adapts itself, through learning networks, and the use of metrics and feedback processes.

Under this theory, writers such as Campbell (2012) expand the engagement of "smart" cities beyond the involvement of communities to larger networks of cities, whereby cities learn from each other best practices in governance and management, and convert such learning to innovative application. City and institutional networks have been set up for this purpose, e.g. "Smart Cities" supported by the European Regional Development Fund (www.smartcities.info), "European Smart Cities" which benchmarks and outlines a "smart" cities model (www.smart-cities.eu), etc. Cities and their agencies have the capability to learn, and with the aid of ICTs, can incorporate feedback loops for re-learning and adaptation. The introduction of new knowledge and technologies, together with adapting traditional knowledge and practices, builds flexibility, a quality of city resilience (Arup 2014). This focus on trial-and-error learning draws on organizational learning theories developed by

Donald Schön in *The Reflective Practitioner* (Schön 1983) and in his two-volume set with Chris Argyris (Argyris and Schön 1978, 1996).

Implicit in the process of learning, re-learning and adaptation is the ability to assess performance, in particular, through metrics or performance indicators defined according to a city's goals. For example, as part of sustainable development and city resilience strategies, cities may have greenhouse gas emissions (GHGe) reduction targets or citizen health and well-being indicators. Cohen's (2012a) "Smart Cities Wheel" involves 100 indicators in six "smart" categories—economy, environment, governance, living, mobility and people—for cities to track their performance and adapt policies towards their goals. Walters (2012) describes the interconnected processes of monitoring, managing and using gathered data for future design as "virtuous cycles in city planning and operation" that lead to innovation.

4.4 Investing for the Future

Assumptions: The "smart" city is cognizant of its human, social and physical stocks of capital, and invests in technologies and functions that have the potential to reap greater economic, social and environmental benefits.

Another group of theorists frame "smart cities" from a resource or business perspective. Caragliu et al. (2009) emphasize stocks of capital, believing "a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance". Recognizing cities' limited resources in the quest for sustainable development, Frenchman et al. (2011) argue that the "smart" use of technology could help cities transform and grow sustainably. For example, this includes the implementation of digital infrastructure and increasing access to information and the knowledge economy, managing long-term risks through monitoring and feedback systems, and facilitating new "city-making" processes such as urban prototyping, etc. "Smart" cities involve "savvy business and development decisions" as part of economic sustainability (Kotkin 2009), and developing a robust technological foundation on which to innovate city business processes (Kuk and Janssen 2011).

A report by The Climate Group et al. (2011) highlighted the potential for cities to realize savings and value through investments in "smart" applications. It urges cities to understand the value chain involved, so as to capture positive externalities and to explore new business models such as revenue streams from technology services. Thus, economic performance and sustainability, and perceived return on investment (ROI) are considerations in the formulation of "smart" initiatives.

On one level, the economic performance and long-term sustainability of cities may be a major consideration and driver in cities' conceptualization and adoption of "smart" applications. On another level, the business performance of "smart"

applications, in relation to a city's technological capabilities and resources, its short and long-term objectives, as well as the perceived return on investment (ROI), are factors in determining the form and extent of these "smart" applications. These are also related to earlier points on organization and governance (e.g. city's capacity, available resources, etc.), formation of partnerships between city governments, businesses and communities (e.g. business model of "smart" applications, funding and implementation models, etc.), and the use of metrics that help to gauge business performance.

5 Case Studies: Concepts and 'Smart' Initiatives

Table 1 summarizes cities' initiatives in relation to the four theories and includes several websites related to the efforts. The "smart" initiatives presented below are non-exhaustive, and have been selected to illustrate "smart" and innovative practices. The governance and geography of the six initiatives vary widely from the municipality of Boston—comprising 617 K people (15 %) and 125 km^2 (1 %) of the 4.5 million people and 11.7 K km^2 within the metropolitan statistical area[2]—to the city-state of Singapore—comprising all 5.5 million people and 718 km^2 within the nation.[3] The public entities overseeing the initiatives also varied from Mayor's Office facilitators to newly established Authorities and public-private partnerships.

5.1 Boston, Massachusetts, U.S.A

Cohen (2012b) ranks Boston as North America's "smartest city", citing its entrepreneurial and innovation ecosystem, in particular, the Mayor's Office for New Urban Mechanics (MONUM). According to Osgood (2013), the city's "smart" efforts use technology and design to engage its citizens and address their concerns. MONUM is not a "skunkworks" laboratory, but is closely integrated with city departments, with whom it jointly develops, tests and implements prototypes. MONUM categorizes its "smart" initiatives as "participatory urbanism" which aims to engage citizens, "clicks and bricks" which focuses on technology infrastructure, and "education". The city's Department of Innovation and Technology (DoIT) has also implemented initiatives such as an open government portal and data cloud, and collaborated with technology providers. Boston's southern waterfront is also branded as an "Innovation District".

[2]US Census Bureau 2010 Quick Facts (http://quickfacts.census.gov/qfd/states/25/2507000.html) and 2000 statistics (http://www.census.gov/prod/2006pubs/smadb/smadb-06tableb.pdf).

[3]SingStat, Singapore (2014): http://www.singstat.gov.sg/statistics/latest-data#14.

Table 1 Examples of 'smart' initiatives and corresponding theories

"Smart machines" and informated organizations		
Boston: Data warehousing and integration (e.g. addresses, crime, public health, etc.) to allow city departments to identify hotspots and analyze problems	**Singapore**: Traffic prediction tool that predicts conditions and allow traffic managers to divert traffic, minimize disruptions and economic costs from delay	**Rio de Janeiro**: "Smart" integrated weather-prediction and emergency response functions, with some reorganization of city departments and processes (http://theinstitute.ieee.org/video/technology-focus/technology-topic/rio-de-janeiro-a-smart-city)
Partnerships and collaboration		
Boston: Citizen engagement initiatives include "Citizens Connect", "Street Bump" and "Community PlanIT"; "Boston About Results" web portal publishes city "scorecard" reports, providing greater transparency (http://www.cityofboston.gov/bar/scorecard/reader.html)	**San Francisco**: MOCI and "Chief Innovation Officer" position roles created to foster entrepreneurial innovation; idea-generating platforms implemented to enhance collaboration, solicit ideas and apps, e.g. hackathons and "ImproveSF"	**Amsterdam**: AIM created to foster entrepreneurial innovation within a "triple helix model" engaging technology providers, research institutions and community; ASC operates as an "open platform" that handles a wide variety of initiatives and does not rely on any single technology provider; "Climate Street" Utrechtsestraat initiative heavily involves local stakeholders and community
Learning, relearning and adapting		
Boston: Part of the "G7" network which exchanges ideas, e.g. public health app based on shared code from Chicago; MONUM evaluates its projects on performance and process of implementation	**Amsterdam**: ASC website with extensive "smart city"-related resources including research findings, and detailed reports (http://amsterdamsmartcity.com/); KPIs set for each project (e.g. CO_2e reduction, number of jobs created, number of citizens involved, etc.), and monitoring of partners involved and investments made; possible upward cascading of changes to tax policies to facilitate exchange of domestically produced energy, following community feedback on decentralized solar energy production in residential areas	**Stockholm**: Stockholm Royal Seaport will incorporate "smart" monitoring technology at the district, block and apartment levels, with a new sustainability unit to build up assessment models and follow up strategies; long-term approach for bi-directional feedback, where ICTs can influence behavior and plans, and evolving behavior and plans can in turn influence ICT

(continued)

Table 1 (continued)

Investing for the future		
Amsterdam: AIM spurs innovation and economic development—technology providers invest resources and stand to gain from commercializing it, while the city and communities benefit from its application	**Stockholm**: Fiber network has generated positive benefits to the local economy, and supports social programs and environmental initiatives; transportation-related initiatives such as the congestion management system and "Journey Planner" (http://reseplanerare.trafiken.nu/bin/query.exe/sn?) aim to reduce CO_2e	**Singapore**: Testing and development of initiatives for own needs, but can subsequently be "exported" commercially to other cities (e.g. water technologies)

"Smart" initiatives include "Citizens Connect", where citizens are engaged to provide feedback that help to enhance municipal services. Through mobile apps, a website, Twitter, or SMS, citizens report issues (e.g. potholes, graffiti, fallen trees, requests for snow plowing, etc.) which generate city work orders requiring action. Another initiative "Street Bump" uses mobile devices' sensors to record the location of uneven road surfaces. In 2011, MONUM and Boston Public Schools (BPS) used "Community PlanIT", an engagement game platform, to gather over 4600 online comments from the community on a school performance metrics and accountability system. DoIT's "Open Government Portal" provides citizens with better access to city data and city government performance indicators (e.g. crime, GIS, permits, Renew Boston Solar Map, etc.), while the "Data Boston" portal contains more than 50 datasets. In 2012, the city collaborated with IBM and Boston University to explore how data from city video cameras, street sensors, citizens' mobile phones, and social media can represent the real-time traffic situation (Dillow 2012), so as to optimize traffic flow and reduce vehicle emissions.

5.2 San Francisco, U.S.A

Cohen (2012b) ranks San Francisco as North America's second "smartest city", noting its environmental leadership and "thriving entrepreneurial economy". Miller (2013), from the Department of the Environment (SF Environment), cites Cohen's definition of "smart cities" as the concept and basis "to take (our) sustainability operations to the next level", achieving "cost and energy savings, improved service delivery and quality of life, and reduced environmental footprint", and to be carbon-free by 2030. Its "SF Energy Map" shows locations of buildings with solar

installations and lets users calculate the photovoltaic potential for properties, while "Honest Buildings" is an online network that shares energy-efficiency building strategies. The "ChargePoint" app monitors 110 public electric vehicle (EV) charging stations, while "SF Park" distributes real-time information on parking availability, adjusting parking rates to match demand. The city recently passed its "Existing Commercial Building Ordinance", which requires commercial buildings with more than 10,000 square feet to report energy usage data to the city, with the intention that owners and managers will address inefficiencies (Nutter 2012).

The city encourages entrepreneurial innovation and the use of open data through the Mayor's Office of Civic Innovation (MOCI) and Department of Technology. Mayor Lee (2012) describes the government's role as a "convener" in encouraging experimentation, declaring October as the city's "innovation month". Initiatives include an open data policy and legislation, with the "DataSF" portal containing more than 500 datasets and a showcase of apps. The city's "living innovation zones", part of its "CleantechSF" initiative, aims to encourage businesses to use city-owned properties and public assets to pilot clean technology, products and design concepts. Idea-generating platforms have also been initiated by private organizations, community groups and city agencies. For example, through the "ImproveSF" online collaboration platform, the Planning Department issued the "Green Connections Challenge", soliciting ideas on making walking and cycling easier and safer, and ideas and suggestions for routes and activities. Other idea-generating platforms include hackathons[4] such as "Unhackathon" and "Summer of Smart", which produced the "Smart Muni" app that tracks city buses in real time and identifies transit system incidents.

5.3 Amsterdam, Netherlands

The Economist's (2012) "smart" cities report contrasted "problems" of "top-down" projects (e.g. Masdar, Songdo City, etc.) with Amsterdam's "bottom-up" approach, which relies on a collaborative platform rather than a master plan. The Amsterdam Smart City (ASC) platform was initiated by the Amsterdam Innovation Motor (AIM),[5] the City of Amsterdam and technology providers. ASC provides test-beds for initiatives that contribute to CO_2e reductions, economic development and improving the quality of life. There are more than 30 initiatives implemented by over 70 partners, categorized under five themes, living, working, mobility, public facilities and open data.

Energy-focused initiatives include "Geuzenveld sustainable neighborhood" where more than 500 households received smart meters to raise energy awareness

[4]Intensive one or multi-day workshops during which programmers write code to address pre-specified 'challenges' using newly available data and resources.

[5]In 2013, after the time of the study, AIM merged with the Amsterdam Economic Board.

and influence consumption behavior, and the "ReloadIT" smart electric vehicle(EV) grid where photovoltaic supply is matched with EV energy demand to optimize the use of renewable energy. Under the "Zuid Oost laws and regulations" initiative, the city is considering the implementation of a "freezone" for the testing of sustainability ideas, where rules and regulations are minimized. Amsterdam's "Open Data" portal contains datasets from 19 categories, while "Apps for Amsterdam" encourages app development along the themes of safety, mobility, vacancy, energy, tourism and culture, and democracy. The Utrechsestraat "Climate Street" initiative is a collaboration between local entrepreneurs, the city and technology providers. The group mapped out the base measurements of energy consumption and CO_2 and NO_2 emissions along the street, and introduced initiatives such as smart meters, displays on energy consumption, smart plugs to automatically dim or shut down appliances, dimmable lamps and tram stop lighting, solar-powered BigBelly waste bins, centrally located reverse osmosis water sources for cleaning vehicles, clustering and optimization of logistics and deliveries, etc.

"Almere smart society" is a collaboration between the Almere Economic Development Board and technology providers providing digital infrastructure to facilitate interaction between citizens and public organizations. Car navigation devices are used to analyze traffic flows and internet video communication is used in health care. CISCO implemented the first "smart work center" (SWC) in an Almere residential community to reduce transportation demands and increase productivity, as an office center equipped with workstations, telepresence teleconference equipment, a childcare center, restaurant, etc.

5.4 Stockholm, Sweden

The 2012 Smart Cities Expose report featured Stockholm as a city which "is doing a few things right" (Smart + Connected Communities Institute 2012). Stockholm's Vision 2030 is "…to become one of the world's cleanest, safest and most beautiful cities where Stockholm is a world leader in information technology and in the development, commercialization and application of new environmental and energy related technology" (City of Stockholm 2011). Stokab, a city-owned infrastructure company, implemented an extensive fiber network that extended from the financial center to the region, serving as backbone infrastructure to support the city's innovation efforts. Stockholm's Green IT strategy aims to use IT to reduce its environmental impact, addressing transportation, energy use, land use, water and waste management, GHGe reduction, etc.

Recognizing that the transportation sector contributes to 31 % of the city's CO_2e, the city aims to "create a long-term sustainable transport system, based on new technology, non-fossil fuels, and more information" (City of Stockholm 2011). In 2006, it developed a variable toll rate traffic and congestion management system

with IBM, involving in-car transponders and optical character recognition to identify license plates. IBM (2010) reported that the system had reduced traffic by 20 %, average travel times by 50 %, and the amount of emissions by 10 %. Other initiatives include providing comprehensive transportation information (e.g. timetables, routes, real-time traffic speeds, incidents, road works, etc.) and a journey planner that estimates the length and cost of the journey and the estimated CO_2e per month weighted by vehicle fuel type.

"Smart" efforts will be extended to sustainable development projects such as Stockholm Royal Seaport, which aims to reduce its per capita CO_2e to 1.5 tons by 2020, and to be "free of fossil fuels" and "climate-neutral" by 2030. The district will comprise a "smart ICT" open and shared communications infrastructure, integrated city management system, street lighting, transport, education, health services, etc. (Stockholm Royal Seaport 2013). The district will also incorporate a smart grid and a vacuum waste collection system that includes user-level waste weighing, a single kitchen sink food waste chute, and energy recovery from the collection system.

5.5 Singapore

Singapore's "smart" efforts center on the application of ICTs in government, society and the economy. The Infocomm Development Authority's (IDA) Intelligent Nation 2015 master plan aims to harness ICTs as "enabling infrastructure" (Tay 2013) and to achieve targets of being "number one in the world in harnessing infocomm to add value to the economy and society", a "twofold increase in value-added of infocomm industry to S$26 billion", a "threefold increase in infocomm export revenue to S$60 billion", the creation of "80,000 additional jobs", "90 % of homes using broadband", and "100 % computer ownership in homes with school-going children". The recently announced "smart nation" platform includes initiatives such as "creating standards for Internet of Things@Home" (IDA 2014). The Economic Development Board (EDB) envisions Singapore as a 'living lab' that tests and develops innovative solutions for city management and the built environment.

"Smart" efforts include the "e-Citizen" web portal with over 385 e-services from 60 ministries and statutory boards (e.g. online filing of income and property taxes, paying mortgage loans, making medical appointments in public health centres, etc.), the "data.gov.sg" portal with over 5000 datasets, "OneMap" geo-located data, etc. For example, users can access data on all property transactions by location, property type, transaction period, price range, etc., visualize residential address locations to schools, or search for rental of government-owned property and space. Mobile apps that provide information include "MyENV" on stormwater levels, air quality, and dengue fever occurrences, "TransportSG" on traffic speed, incidents, electronic road pricing charges, and number of parking lots, and "Police@SG" on

crime statistics. Government agencies support private hackathons (e.g. "UP Singapore") to seek new ideas and apps.

In terms of infrastructure, a 1Gbps fiber network is planned to connect 60 % of households, "Wireless @SG" provides free wi-fi in public areas, while near field communication e-payment solutions are being studied. The "intelligent energy system" initiative is a collaborative pilot project by the Energy Market Authority and Singapore Power, an energy provider, to test new smart grid applications. These include equipping households with a "smart meter" to view electricity consumption data, and in future phases to develop advanced management applications (e.g. time-of-use tariff information, demand response and energy management, outage management, integration of EV charging and vehicle-to-grid functions, etc.). The Land Transport Authority's (LTA) "smart" initiatives include the "e-Symphony" integrated fare card system and the "traffic prediction tool" that anticipates and helps the management of traffic flow to minimize congestion. New pilot "smart" initiatives will be tested at the Jurong Lake District, including autonomous buggy transportation in parks, real-time microclimate monitors, a smartphone platform that enables users to contribute data on the quality of public transportation trips, park lighting that responds to motion and natural conditions, etc. (IDA 2014).

5.6 Rio de Janeiro, Brazil

Rio de Janeiro's "smart" program is synonymous with its Rio Operations Center (COR). Developed with IBM, COR integrates the functions of over 30 city agencies, private transportation and utility companies, including emergency response (BBC 2013; IEEE 2014). According to Mayor Eduardo Paes, COR and ICTs are instrumentsthat benefit citizens, allow quick and reliable communication, and improve city operations (Sterling 2011). Carlos Osorio, Secretary for Conservation and Public Services, describes COR as a "collaborative tool" and "catalyst to make the broader metropolitan area function better" (Smart + Connected Communities Institute 2012: 24). Hamm (2012) describes COR as the "first such facility in the world" that coordinates the complex "human-made and natural systems of a city in a holistic way".

COR involves the use of real-time data (e.g. video from 560 traffic cameras) to manage traffic and crowd-intensive events, e.g. the Carnival, 2014 FIFA World Cup, etc. COR integrates a situation room where city leaders and emergency response officials communicate and make decisions. In 2010, floods and mudslides caused 200 deaths and made 15,000 homeless (Heim 2011). With COR, the city can forecast the weather 48 h ahead, predict wind speeds, rainfall and runoff intensities and the impacts of floods and landslides, coordinate its emergency response agencies and deploy resources such as emergency shelters. COR's citizen warning and communication system includes sirens, SMS, email, its web portal, Facebook, Twitter, etc.

6 Findings and Discussion

The cities' concepts and perceptions of "smart cities" and different approaches were assessed against the four theories, and key initiatives are summarized in Table 1.

6.1 "Smart Machines" and Informated Organizations

6.1.1 "Smart" Machines

Several cities used ICTs for automation and intelligent functions—i.e. "smart machines". For example, Rio's COR uses data on soil composition, topography, population, land use, and hydrology models to predict the weather and impacts. The rain forecasts, which assist decision-making, are reportedly 91.8–93.6 % accurate (Treinish et al. 2012). According to the LTA official, Singapore's "Traffic Prediction Tool", developed with IBM, uses algorithms to predict traffic conditions 30 min in advance, allowing traffic managers to divert traffic, minimizing disruptions and economic costs from delay. Boston's data integration efforts (e.g. address points, crime, Constituent Relationship Management System, code violations, public health records, etc.) allowed city departments "to easily identify and analyze problem(s)" and "hotspots to be identified and mapped" (Lane 2013). A number of observations were drawn. First, cities need infrastructure and processes to collect and organize data (e.g. sensors, data integration and warehousing), and algorithms and visualization tools for analyses. Second, these functions tend to be immediate-term city management operations with behavioral rules, e.g. emergency responses linked to prediction threat levels. Third, integrating data from multiple sources may lead to new insight, as seen in Boston's case, or lead to enhanced city functions, as seen in Rio's case.

6.1.2 "Informating" and Organizational Change

While most 'smart city' efforts involve some level of automation, the efforts have different extents of "informating" and re-organization. For Rio's COR, reorganization is inseparable from its "smart" functions; predicting landslides will be incomplete unless information is relayed to emergency response agencies close at hand. Osgood (2013) revealed that given the prototypical nature of "Street Bump" and the challenges faced in changes in processes and management practices, Boston's Public Works Department and MONUM took an incremental approach to change. According to the Singapore LTA official interviewed, there were no organizational changes arising from the use of the "Traffic Prediction Tool", as existing traffic management staff took on the trial predictive functions (Table 1).

6.2 Beyond "Smart Machines": Partnerships and Collaboration

6.2.1 New Innovation Agencies

Many of the examined cities consciously created new agencies to lead "smart" efforts. Some play a facilitator role, e.g. Amsterdam's AIM, and Singapore's "Smart Nation Program Office". Others have been charged to spearhead innovation, such as Boston's MONUM, and San Francisco's MOCI and "Chief Innovation Officer" position.

6.2.2 "Smart", Citizen-Focused Governance

The motivation for cities to achieve better governance—e.g. improved delivery of city services, engagement of citizens, creating transparency, etc.—through "smart" initiatives was evident. For Boston, this can be seen from the "Boston About Results" scorecard web portal that publishes city reports (e.g. number of permits issued online, percentage of streetlight outages addressed in 10 business days, etc.), "Citizens Connect" and "Community PlanIT", and for Singapore the government e-services. More investigations will be needed to evaluate the impacts of new service channels against traditional methods of delivery, as well as combined impacts.

6.2.3 Collaboration and Leveraging Local Human Capital

Cities were cognizant and took a collaborative approach in implementing their "smart" initiatives. According to a city official interviewed, Amsterdam based its efforts on the triple-helix model, which taps the "intellectual capital of universities, the wealth creation of industries, and the democratic government of civil society" (Leydesdorff and Deakin 2011). The development of Stockholm's Royal Seaport involves the city, developers, stakeholders, technology providers and research institutions. For Singapore's JLD, agencies fund and implement prerequisite infrastructure (e.g. fiber networks, data sensors) upon which technology providers build solutions. Cities (e.g. San Francisco, Boston, Amsterdam, Singapore, Stockholm) also commonly use hackathons to engage partners and seek innovative ideas.

Several factors influence cities' structuring of partnerships. First, the choice of technology provider(s) depends on their levels of expertise and business models. For example, few technology providers may be able to implement COR, integrating analytical capabilities, software and hardware like IBM. Technology providers may choose to collaborate as consortia, or not, due to their business interests. Second, the nature of each project matters. For example, cities may structure less public involvement for high-risk initiatives such as COR emergency response, in contrast to pothole repairs. Third, cities with a clear picture of objectives and technologies (e.g. setting up COR, a prediction-response function) may handpick specific partners, instead of crowd-sourcing ideas.

6.2.4 Avoiding Lock-In

Some cities set out to avoid technological "lock-in" (e.g. proprietary data formats, inflexible partnerships with technology providers), to ensure long-term sustainability. For example, Boston's MONUM takes an open source ideas approach, ASC is an open platform not relying on any single technology provider, and Stockholm Royal Seaport adopts an open and generic ICT infrastructure.

6.2.5 Overcoming Challenges in Collaboration

A challenge faced in collaboration is overcoming friction and expectations between partners. For Singapore, the EDB official interviewed cited agencies' different "level(s) of ambition" as a challenge; for instance, an economic development agency could be interested in "disruptive solutions", whereas a line agency could prefer "tried and tested low-cost solutions". To close the gap with operational agencies, MONUM's approach is to "broker the partnerships with the thought leaders within these agencies" (Osgood 2013), establishing buy-in and ensuring practical initiatives. Tratz-Ryan (2011), analyzing Rio's COR, highlighted that integration across agencies "will not happen overnight", and stressed the important role of people in uniting different functions. Hence, the human element that establishes the middle ground is a success factor.

6.3 Learning, Relearning and Adapting

6.3.1 Continual Learning

Most of the cities examined learn and share their experiences, for example, hosting delegation visits (e.g. Stockholm's Professional Study Visits on city governance and green efforts), organizing and attending conferences (e.g. Amsterdam's "Smart City Event", Singapore's "World Cities Summit"), and websites (e.g. Amsterdam's ASC website with extensive research findings and detailed "Smart Stories" reports). Ideas are also exchanged through city networks such as "G7" in North America. For example, based on shared code obtained from Chicago, Boston released its own public health app during the 2013 flu epidemic (Osgood 2013).

6.3.2 Use of Metrics

While this study could not obtain specific data, cities were generally aware of the use of metrics in assessing projects' performance. For Amsterdam, key performance indicators (KPIs) are set (e.g. CO_2e reduction, number of jobs created, etc.) and AIM monitors the partners involved and investments made for each project.

Boston's MONUM evaluates its projects on two dimensions, in terms of projects' performance (e.g. how "Citizens Connect" changed behavior) and the process of implementation (e.g. effectiveness in sourcing ideas) (Osgood 2013). Stockholm's Royal Seaport plans to incorporate "smart" monitoring technology at the district, block and apartment levels, and a new sustainability unit will focus on "building up assessment models and follow up strategies" (Claeson 2013).

6.3.3 Use of Feedback Loops

Some cities incorporate feedback loops from their "smart" initiatives. For San Francisco, data from EV "Charge Point" stations are collected to help determine future strategies, e.g. new charging station locations (Nutter 2012). For Singapore's traffic prediction, according to the LTA official interviewed, information is used for traffic management (e.g. relayed to road users) in the immediate term, operational improvements (e.g. changes to road junction geometry and signaling) in the medium term, and for planning purposes (e.g. traffic modeling) in the long term. For Amsterdam, arising from a pilot project involving decentralized solar energy production in residential buildings, the community provided feedback and advocated changes to tax policies to facilitate the exchange of domestically produced energy. According to the AIM official interviewed policies like this, if adopted, may cascade to the national level. For Stockholm's Royal Seaport, Bylund et al. (2011) outline a long-term approach for bi-directional feedback, where ICTs can influence behavior and plans, and evolving behavior and plans can in turn influence ICTs, to the extent of "discarding… outdated technologies".

Feedback mechanisms, when strategically incorporated through bootstrapping, allow cities to address long-term issues, yield wider benefits, and build up capabilities. For example, to address Rio's flooding and landslide hotspots, preemptive actions can be taken in the form of infrastructure (e.g. retaining structures, stormwater management systems, etc.) and policy adjustments (e.g. land use policies around high-risk zones).

6.4 Investing for the Future

6.4.1 Returns-On-Investment and Funding

From the cities examined, there was no evidence of cities adopting a strong return-on-investment (ROI) business perspective for their "smart" initiatives. For Singapore's "Traffic Prediction Tool", the LTA official interviewed highlighted that overall benefits were difficult to assess for the trial project; notwithstanding that, negative externalities resulting from traffic delays were considered to justify expenditure for the initiative. Some cities do not have dedicated budgets for their "smart" initiatives, for example, Amsterdam's AIM does not fund or own initiatives

but provides manpower and organizing resources for ASC. Boston's MONUM receives funding from non-profit foundations (e.g. MacArthur Foundation, Bloomberg Foundation), the State, and line agencies for various initiatives. More investigation will be needed to analyze interactions between city objectives, perceived costs-benefits and ROI, and funding models.

6.4.2 Directly Monetizing "Smart" Initiatives

There was also no evidence that cities directly monetized their "smart" initiatives. For example, instead of the sale of data, many cities (i.e. Boston, San Francisco, Amsterdam, Stockholm, Singapore) have taken an open data approach, being aware of the longer-term benefits to spur innovation, improve the delivery of city services and enhance community engagement.

6.4.3 Longer-Term Wider Benefits

Some cities adopt a longer-term perspective on the wider economic, environmental and social benefits. For Amsterdam, AIM's interest is to spur innovation and economic development. Under their win-win model, technology providers invest resources as business decisions, own the product and stand to gain from commercializing it, while the city and communities benefit from its application. Stockholm's fiber network generated "significant positive benefits" to the economy through enhancing the city's attractiveness as a technology and innovation hub with excellent infrastructure and high administrative efficiency (Felten 2012). According to Broberg (Smart + Connected Communities Institute 2012), the network contributed to the city's knowledge economy, buffered it from the economic crisis, and supports social programs and environmental initiatives. In Singapore's case, the test-bedding and development of initiatives primarily meet its own needs, but can be "exported" commercially to other cities, as seen from its water technologies industry. Hamm (2012) sees Rio's implementation of COR as "investing for the long term," a way to mitigate the risks arising from severe weather and flooding.

7 Cities' Different Approaches

Cities have taken different approaches in relation to their characteristics, the nature of their "smart" initiatives, and the business models of their technology providers. Here, cities' approaches are also analyzed in terms of whether they are "top-down", where initiatives are determined and implemented through cities' directives, "bottom-up", where initiatives are grassroots driven, or "middle-out", where city objectives are addressed through a less-deterministic approach involving government initiation combined with the efforts of technology providers and the community.

7.1 Cities' Characteristics

With its small agencies (e.g. MONUM, DoIT), Boston takes a "middle-out"/"bottom-up" and incremental approach that relies on partnerships. It capitalizes on ideas from various sources (e.g. "Community PlanIT" from Emerson College, "Citizens Connect" from MONUM) (Osgood 2013), and matches them to specific needs. San Francisco takes a "bottom-up" approach with small agencies engaging local technology entrepreneurs to stimulate innovation. Amsterdam, through its collaborative ASC platform, typically use "middle-out"/"bottom-up" approaches to tackle different types and scales of initiatives. Stockholm's initiatives range from "top-down" (e.g. network infrastructure) to "middle-out" (e.g. Stockholm Royal Seaport), where its partnership framework and feedback mechanism is designed to support the long-term development of the district. Some of Singapore's initiatives are "top-down"(e.g. traffic prediction), while others, like JLD, are "middle-out". For Rio, COR was implemented as a "top-down" initiative through a mayoral decision (Singer 2012).

7.2 Nature of "Smart" Initiatives

The "smart" initiatives examined range from community engagement platforms (e.g. "Community PlanIT"), programs to meet environmental, economic and social goals (e.g. "Energy Map"), to city-scale infrastructure (e.g. COR, Stokab network). Initiatives of similar nature share common characteristics, for example the "middle-out" approach to develop new sustainability districts (e.g. Stockholm Royal Seaport, Singapore's JLD, Almere Smart Society) through partnerships. "Middle-out"/"bottom-up" initiatives (e.g. Boston's "Citizens Connect", San Francisco's "Unhackathon") involve community engagement and enhancements to city services. Compared to infrastructure, they require less capital resources, and involve communities in their conceptualization and use. The approaches taken for different initiatives do not appear to be "interchangeable". For instance, Rio's COR cannot be implemented through a "bottom-up" approach due to the high degree of expertise needed, and it will be incongruent to implement "Citizens Connect" through a "top-down" approach.

7.3 Technology Providers' Business Models

The nature of technology and technology providers' business models are factors influencing cities' approaches. For example, IBM's partnership with Rio can be described as a "turnkey" model, where the vendor brings forth its technology, innovations and systems integration capabilities. In this model, the city receives a

fully packaged solution that meets its objectives without significant change in the skill set and personnel of the client (i.e., the city). Hence, this model requires shared goals to be established between the technology provider and city, which must also be willing to make capital investments and accept limited partnerships. Cisco's TelePresence technology rethinks the nature of work and commuting. Its model brings forth technology and new solutions to issues that may not already be recognized as problems. By doing so, it is investing in potential new areas where cities may reap benefits (e.g. greater productivity, reduced negative impacts from commuting), creating markets in which it will have a headstart. Stokab, a city-created agency-cum-technology provider, focuses on implementing prerequisite infrastructure that underpins other "smart" initiatives, while building new technical capacity within government rather than adopting a more turnkey approach. For the city, this model encompasses the idea of "sequencing" or "layering" of technologies, while from the business perspective, the base infrastructure may support retail services to be developed by non-governmental third-parties, in this case the delivery of telecommunication services.

8 Lessons for Planners and "Pathways" for Cities

There is no single "smart" model for cities. Table 2 summarizes lessons and best practices for city planners to consider different pathways in their conceptualization and implementation strategies. For example, a city may lean towards a "top-down" approach and position itself to implement large-scale infrastructure in partnership with an expert technology provider. If such an effort is treated as a 'turnkey' project by the city, there may be limited opportunity for capacity building and discovery of new ways to build on the new data infrastructure through 'informating.' However, the city need not follow a traditional "top-down" approach that narrowly seeks solutions to specific problems. Instead, it can invest "smartly" by deliberately creating and harnessing positive spillover effects, and shaping its efforts to be strategic enablers. The city might also incorporate multi-scale feedback mechanisms, taking a long-term view towards reaping maximum benefits through knowledge transfers, and sequential infrastructure development, while avoiding lock-in by remaining flexible in terms of technology and partnership structures.

Another city may lean towards a "bottom-up" approach, e.g. having limited in-house expertise and resources to engage in turnkey projects, and/or having an entrepreneurial grassroots. Yet some grassroots-driven efforts, while innovative, may be unsustainable if robust partnerships with city agencies are not established, or if a longer-term framework is not set up (e.g. city data management, knowledge sharing, data regulatory environment, etc.). The city can focus on developing the collaborative platforms, upon which processes of innovation, knowledge-sharing and implementation are made sustainable for the long-term (Table 2).

Finally, a city may be inclined towards the "middle-out" approach of maintaining a degree of openness and test-bedding initiatives through an innovation-

Table 2 Lessons for planners: best practices to consider

"Smart machines" and informated organizations
Identify "smart machine" functions that provide speedier and more accurate results within and across city agencies, and establish infrastructure and processes for data collection, integration, interpretation and analysis, etc.
Identify complementary informating functions and reorganize city agencies to harness automation, e.g. incorporating data analytics in planning support systems and evolving planning processes that inform, collaborate and co-create with the community
Partnerships and collaboration
Identify appropriate "smart" approach/"pathway" appropriate to the context of the city and initiative, i.e. "top-down", "middle-out" or "bottom-up"
Create innovation-fostering agencies that understand technologies, organization and processes of and across agencies, to form partnerships and initiate projects that support city economic, environmental and social objectives
Identify partners including city agencies, technology providers, research institutions, and the community
Implement citizen-focused initiatives to expand available city resources, provide innovative ideas, engage citizens and allow greater transparency
Anticipate and address possible challenges in collaboration, whether arising between partners or from technology gaps
Learning, relearning and adapting
Establish and use metrics to assess the effectiveness of "smart" initiatives against environmental, economic or social sustainability targets, as well as to improve their processes of implementation
Incorporate multiple, multi-scale feedback loops to assess the effectiveness of initiatives using metrics, and apply feedback inputs to refine cross-agency processes and long-term strategies
Avoid lock-in through the use of open data and open-source platforms instead of proprietary data formats, and through the structuring of partnerships where not a single technology provider or technology dominates
Establish avenues for continual learning and city knowledge management, e.g. through conferences, city networks, learning visits, publications, etc.
Recognize the cost, focus, and speed differences **between turnkey systems** delivering new capability, **and capacity-building efforts** that assist agency staff in discovering new ways to harness digital data and information technologies
Investing for the future
Define and pursue city goals and long-term strategies that reap wider benefits to ensure that there are net environmental, economic or social benefits in the long-term, beyond short-term objectives
Establish clear objectives, and assess ROI (return-on-investment) from both a financial and non-financial perspective, to evaluate "smart" initiatives and to justify investments
Sequence development and investment to carefully plan the implementation of prerequisite backbone infrastructure, or the use or testing of specific technologies

focused agency and/or collaborative platform. While it may not achieve the technological benefits of a "top-down" turnkey approach, or the level of innovation of a "bottom-up" grassroots approach, the "middle-out" approach may provide more flexibility in matching technological innovation to organizational capacity.

This approach may also be able to address initiatives ranging from smaller-scale community engagement to larger-scale infrastructure projects, sustain partnerships, and reap wider long-term benefits. In this way, the city can concentrate on developing a strong collaborative framework, and incorporate systematic learning and feedback loops to ensure long-term improvements.

9 Conclusion

The study of six "smart" cities found that overall, planners' concepts were supportive of, and included elements of the four theories of being "smart". The four theories were complementary and not mutually exclusive; the cities adopted various combinations of elements according to their specific contexts, and had different approaches and partnership frameworks depending on the nature of the initiatives.

These findings suggest multi-dimensionality in being a "smart" city. On one dimension, being "smart" involves harnessing ICTs, for example through automation, to achieve optimum results and to meet economic, environmental and social objectives. But there is enormous potential for cities to consider how they can "informate", where new digital information generated through automation can be used to exploit and innovate organizational structures and processes within and across city agencies, as well as with technology providers, research institutions and the community through sustainable partnerships. For example, through planning support systems that generate insight based on analyzing data obtained from city sensors, planners could evolve planning processes to inform, collaborate and co-create with the community. Being "smart" also involves prudent decision-making that matches a city's resources and capabilities with its objectives, maximizing long-term benefits, and maintaining a flexible approach that fosters innovation. Being "smart" involves continual learning and feedback monitoring, for cities to remain aware and nimble. Could these dimensions conflict with one another? Yes. For example, a city that focuses on automation to achieve efficiencies, without adequate attention to longer-term city objectives and ROI, or building up robust partnerships, may be missing the big picture. City leaders and planners need to be "smart" about being "smart".

The multi-dimensionality of "smart" cities may add to the diversity in definition, and discourse will likely continue on what being "smart" or "smarter" entails. Yet this multi-dimensionality reflects the complex nature of city planning and management and difficult issues that "smart" initiatives attempt to address. This study set out to uncover concepts and perceptions of "smart" cities. Rather than focus on a definition of the term, we have tried to identify viable pathways and learning in order to provide an applicable guide for city planners to consider the various theories and best practices, as they embark on their own "smart" initiatives.

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