Smart Cities: Concepts, Perceptions and Lessons for Planners

by

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Abstract

Today, there appears to be a visible trend in the use of the "smart" prefix. For example, cities are branding themselves as, or striving to become "smart" cities. Planners and policy-makers espouse "smart growth". Infrastructure planning involves "smart grids" for energy, "smart networks" for information and communications technologies (ICTs) and "smart mobility" in transportation. The "smart" term has also been stretched, where being "smart" is trounced by being "smarter". Being "smart", or "smarter", is perhaps seen as the next frontier for city planning, policy-making and management.

A common underlying theme in "smart" cities is the application of technology to city planning and management, that leads to greater optimization of time and resources. However, definitions of "smart" cities remain elusive, and an inadequate understanding may lead cities to possible image or technological traps, heavy investments in ICTs and infrastructure without maximizing their potential, or to focus on "smart" technologies for short-term solutions without adequately considering the long term. As cities grapple with rapid urbanization and goals for sustainable development, resource management and climate change mitigation, learning about being "smart" will be timely and invaluable for planners.

This study examines six "smart" cities - Boston, San Francisco, Amsterdam, Stockholm, Singapore and Rio de Janeiro – assessing city officials' perceptions and concepts of "smart cities" and their "smart" initiatives. Their efforts and approaches are analyzed against four theories of "smart" cities; (a) "smart machines" and organization, (b) engaging communities, organizations and businesses, (c) learning and adaptation, and (d) investing for the future. From the research, learning points and best practices are extracted, to serve as an applicable guide for cities as they embark on their "smart" initiatives.

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God, my anchor.

Tuan-Yee Ching
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Chapter 1 - Introduction

In today's world of planning, there appears to be a visible trend in the use of the "smart" prefix. For example, cities around the world are branding themselves as, or striving to become "smart cities". Planners and policy-makers espouse "smart growth". Infrastructure planning involves "smart grids" for energy, "smart networks" for information and communications technologies (ICT) and "smart mobility" in transportation. The "smart" term has also been stretched by technology firms like IBM, where being "smart" is trounced by being "smarter"[1]. Being "smart", or "smarter", is perhaps seen as the next frontier for city planning, policy-making and management.

A common underlying theme is the application of technology to city planning and management, leading to greater optimization of time and resources, and resulting in more efficiency. Yet, the definition of "smart" cities is still elusive; does it refer to city form, infrastructure and development, or processes in city planning and management, or city governance and organization, or all of the above? Will an unclear understanding of being "smart" lead cities in their pursuits to possible image or technological traps? Does being "smart" require cities to invest heavily in ICTs and infrastructure? In their efforts to plan and manage city resources, will there be a danger for cities to leap in and incur resources without recognizing fuller potentials of being "really smart"? Will cities be in danger of focusing "smart" technologies on short-term solutions without adequately addressing underlying long-term causes? Will rapid technological changes result in early obsolescence of city investments?

Given the prefixing trend in planning circles, and more critically, the raised consciousness in policy-makers' minds, answers to these questions will be timely. As cities grapple with rapid urbanization and goals for sustainable development, resource management and climate change mitigation, learning about being "smart" will be timely and invaluable for planners.

Research Question and Objective

How are city planners - i.e. in a broad sense encompassing urban planners, transportation planners, infrastructure planners, etc. - conceptualizing a "smart city"? Are planners' perceptions and concepts of "smart cities" consistent with existing theories of "smartness"?

The objective of the research is to compare planners' perceptions and concepts of "smart cities" with existing theories of being "smart" and to identify possible gaps and opportunities. Through the findings and analysis, the research aims to provide an applicable guide for planners working in different city contexts, to consider

[1] IBM's program for cities is termed "Smarter Cities".

various theories and learning points arising from the research in their formulation and implementation of "smart cities".

Research Methodology & Thesis Outline

The thesis begins, in Chapter 2, with a literature review that provides an overview of "smart cities", "smart" planning movements and global technology providers around the world today. The chapter also outlines four main theories of being "smart".

To address the research question, six "smart cities" – Boston, Massachusetts, U.S.A., San Francisco, U.S.A., Amsterdam, Netherlands, Stockholm, Sweden, Singapore and Rio de Janeiro, Brazil – were shortlisted as case studies. The key efforts of these cities are sketched in Chapter 3.

Chapter 4 contains the analysis of concepts, perceptions and applications of "smart" initiatives in these six cities against the theories, based on data obtained through phone interviews and email correspondence with city officials.

Finally, in Chapter 5, general findings pertaining to the overall conceptualization and implementation of "smart cities" are presented as a framework that serves as an applicable guide for city planners.

Chapter 2 - Literature Review

This chapter begins with a survey of "smart cities" - "smart" cities that may be self-professing or aspiring cities, or those that have been described as "smart" by others, such as their technology providers. In many cases, the cities are characterized by the functional application of technologies linked to their technology providers; hence this survey also takes a brief look at the nature of these technologies and their providers. The list of cities and technology providers forms the basis for selecting case studies for further detailed examination.

Next, the chapter examines theories and concepts of being "smart". This review will begin with theories of "smart machines" and opportunities for their application in complex city functions. Extending these are theories of human-machine collaborations and the re-tooling of organization structures and processes, to frameworks of planning and governance that involve engaging the community. Returning to the common definition of "smartness", theories involving networking and collaboration, learning and relearning, are outlined. Finally, a business perspective of "smart cities" is described.

A Survey of "Smart Cities"

Cities

Many cities around the world are professing, aspiring to be, or have been described as "smart cities". Through desktop research of "smart cities" literature, reports from technology providers and cities' news, a survey of these cities is compiled as shown in Appendix 1. The list is non-comprehensive and is likely to expand as more cities look to the application of ICTs and new technologies as an integral part of their city functions. From the survey, without undertaking a full detailed analysis, a number of observations can be drawn.

First, there appears to be a wide and varied notion of "smart cities" across the globe. While all of them share the common theme of adopting ICTs and new technologies, the fields of application range broadly from utilities (e.g. smart grids) to transportation, environmental monitoring to citizen engagement, etc.; few cities directly apply these technologies to city planning (e.g. Issy, Edinburgh, Nanjing, Boston, Syracuse, etc.).

A second observation is that the "smart cities" appear to be in different stages of development. A few cities (e.g. Rio de Janeiro, Amsterdam, Santander, Oulu, Stockholm, Singapore, etc.) have already implemented systems that are currently in use, while a large majority appears to be in a conceptual or development phase.

Third, about a third of the cities are reported to be working with major global technology providers such as IBM, Cisco or Siemens. While some cities have named local or regional technology providers and research institutions as partners, the technology providers for many other cities are unnamed and further investigation will be needed to determine these.

Fourth, based on the literature, many of these "smart" efforts appear to have emerged within the last decade. Whilst the application of technology in city planning and management may not be new, a few possible reasons for the emergent "smart" trend could be an increase in the branding of cities' efforts as "smart", the increased application of more widely available ICTs, as well as technology providers' increased efforts to partner these cities under a "smart" theme.

Global Technology Providers

ABI Research (2012) estimates that "the market for technologies that feed into and support Smart City programs and projects will grow on a global basis from $8 billion in 2010 to exceed $39 billion in 2016", while Pike Research (2011) estimates that "investment in smart city technology infrastructure will total $108 billion during the years from 2010 to 2020".

As identified from the survey, technology providers play an important role in partnering cities; in particular, major global technology providers such as IBM, Cisco and Siemens have been heavily involved in efforts to encourage cities in the adoption of ICTs and new technology. These efforts are often framed in the context of sustainable development, for example, in the efficient use of energy and resources, reducing GHGe, improving and enhancing city services, etc. The efforts of IBM, Cisco and Siemens, together with their underlying concepts of "smart cities", are outlined here.

IBM

IBM (2010a), which sees a city as a "system of systems", emphasizes the role of ICTs in enabling how planners and policymakers understand how these systems work, interact and share information, to facilitate better decision-making. This is based on the theory that observations and measurements at the individual person level can be made with ICTs instrumentation and aggregated, and in turn, the "choices and construction" of city systems influenced to affect individuals (Harrison & Donnely 2011). In a wide range of city sectors and functions, including transportation, energy and utilities, retail, healthcare, airports, social services, communications, education, public safety and economic development, IBM has envisaged and customized solutions for cities.

IBM highlights that "smart is a verb", encouraging cities, in particular city leaders, to use such solutions to make decisions "based on evidence, not on habit or opinion or gut". They portray a picture where leaders "using even more powerful tools, sharpened by ever more precise information and insight, ... are creating the big transformational shifts that reverberate through their organizations", and who are "anticipating, rather than merely reacting to events", and "seizing competitive advantage" (IBM 2012a).

As part of their efforts, IBM has initiated a $50 million Smarter Cities Challenge program, where it works with recipient cities to analyze their data and systems to suggest more efficient and effective solutions to address the cities' priority issues. For example, in Syracuse, New York where an outflow of jobs and population has resulted in a high number of vacant properties, IBM is working with the city to establish a system to understand, analyze and predict vacancy trends. This will facilitate the city in making decisions on neighborhood planning and development (IBM 2011a).

Cisco

Cisco (2012a) emphasizes how cities address and overcome challenges "by using networked information to transform urban centers into networked communities", i.e. "smart + connected communities". Through the network as the "underlying services delivery platform" that "connects everyone to everything", they envisage and apply solutions that allow citizens, businesses and governments to "realize sustainable economic growth", "enable environmental sustainability through resource management and operational efficiencies", and "enhance quality of life". These include the utilities, transportation, safety and security, real estate, and government sectors, with solutions also extending to homes and work places. For example, Cisco's "smart work centers" in Amsterdam are hot-desk office spaces and conference rooms located near residential areas with advanced networked telecommunications facilities for working and collaboration, e.g. TelePresence (Cisco 2011a). The aim of these work centers is to reduce or eliminate commuting, and companies and/or workers can flexibly rent them; if successful, such work centers may have positive impacts on land use and transportation planning.

Part of Cisco's efforts include the Smart + Connected Communities Institute, which aims to provide a "central hub for city planners, developers, academic institutions, systems integrators and visionary leaders in which to collaborate on the issues involved in the (re)development of sustainable cities" (Smart + Connected Communities Institute 2012a). It hosts blogs and online fora, and its publications include white papers, case studies, reports and presentations on the application of ICTs and new technology in various city sectors and functions.

Siemens

Siemens frames its efforts in the context of urban sustainability. In collaboration with the Economist Intelligent Unit, Siemens publishes "The Green City Index", a research series ranking more than 120 cities by continent and highlighting their policies and best practices in achieving urban environmental sustainability. Siemens also set up The Crystal in London, the world's largest exhibition focused on urban sustainability, where it aims to provide a "global knowledge hub that helps a diverse range of audiences learn and understand how we can all work to build better cities for ourselves and for future generations" (The Crystal 2012).

Hence, in this context, Siemens sees ICTs as a "fifth utility", an important component of "smart cities" that "can enable increased efficiency and flexibility to use new resources" to "enable sustainable behavior" (Siemens 2010). It thus focuses heavily on integrated technological solutions for sustainable urban infrastructure, in particular, in the energy (e.g. smart grids, energy storage), transportation (e.g. high-speed trains, electric vehicles infrastructure, traffic management), green building (e.g. intelligent Total Building Solutions), environmental, water (e.g. water treatment), healthcare, etc. sectors.

Theories and Concepts of "Smart Cities"

In its usage as an adjective, the word "smart" is commonly understood to be as being clever and intelligent, comprising dimensions of shrewdness, acumen and looking after one's interests, as well as that of learning and being adept. In the context of modern technology, "smart" implies that following processes of computer programming or guidance, some level of intelligent autonomy or automation in action is involved[2]. In the application of being "smart" within the city context, the theories and concepts of "smart cities" can be grouped under four key theories.

Theory A - In the age of the Smart Machine: Smart Machines and Organization

Assumptions: The "smart city" involves the use of ICTs for automation and intelligent functions, and is also "smart" about the way its processes, organization and governance can be reorganized to take advantage of these technologies.

In her theory of "smart machines", Zuboff 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

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

perform tasks repeatedly, reliably and with more control (Zuboff 1988:9). When city functions are taken over by such "smart machines", made intelligent enough through the use of sophisticated data sensors and computing algorithms, they are envisaged to perform more 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 Janeiro, implemented by IBM, is made to predict the amount of rainfall more accurately than standard weather forecast systems and send out text messages to various city departments for flood mitigation operations (Singer 2012). IBM (2011b) highlights that operations centers like this allow cities to "leverage information" across city departments, "anticipate problems and minimize the impact of disruptions" and to "coordinate resources to respond to issues rapidly and effectively". Other sophisticated "smart machines" may employ algorithms or protocols (e.g. systems dynamics) which model and provide predictions, such as the effects of city plans and policies on carbon emissions, and act as decision support tools for city functions (IBM 2011c).

On the surface, it may appear that getting the right algorithms could empower "smart machines" enough. Kasparov (2010) remarked that "weak human + machine + better process was superior to a strong computer alone, and more remarkably, superior to a strong human + machine + inferior process" after an online chess tournament where a team of amateur chess players using normal laptops beat human grandmasters and chess machines. There is an increasing belief that a combination of humans and "smart machines" is necessary, especially in improving business organizational models (Brynjolfsson & McAfee 2011a) and how well humans work together with the machines (Kelly 2012).

These bring us back to Zuboff's second dimension. From automated processes, a "smart machine" also informates, "generates information about the underlying productive and administrative processes through which an organization accomplishes its work", thus creating the potential for organizations to exploit and innovate their own organizational structures and processes (Zuboff 1988:10). Brynjolfsson & McAfee (2011b:41) highlight that "the most productive firms reinvented and reorganized decision rights, incentives systems, information flows, hiring systems, and other aspects of organizational capital to get the most from the technology", and re-engineered production processes to "exploit powerful new information technologies". Gorbis (2011) further analyzes specific areas where humans contribute in the human-machine combination, such as the ability to think, having social and emotional intelligence, and having creativity, intuition, and improvisation. From these perspectives, "smart machines" alone in handling city functions may achieve some base levels of efficiencies; however, when combined with the human element in the processes, for example through retooling organization structures or introducing a qualitative dimension in decision-making, may lead to greater benefits.

The emphasis on good organization, governance and public administration has been underscored as a necessary foundation for "smart cities" by a number of writers and

organizations. Following a workshop for policy-makers on "smart cities", World Bank official Joshi-Ghani highlighted that "the concept of 'smart cities' is really about good governance" (Morier 2012). Belissent (2011) echoes this views, stating that "the real key to being smart is to have an overall management system that allows leaders to coordinate across these smart systems" and that "smart cities required good 'smart' governance". Open Cities, a network for "smart cities", points out in their definition that "the Smart City concept brings together all the characteristics associated with organizational change, technological, economic and social development of a modern city" (Open Cities 2011).

Theory B - Beyond "Smart Machines": Engaging Communities, Organizations & Businesses

Assumptions: The "smart city" involves a collaborative process where city governments engage communities, businesses, research institutions, etc. as partners in a framework that drives innovation and transformation.

Another group of theorists, as Allwinkle and Cruickshank (2011:9) analyze, view "smart cities" beyond "smart machines" analogies, shifting the focus from city functions to governance, and in particular, from a liberal democratic viewpoint. For example, Hollands (2008) adopts a critical view of 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. Townsend (2011) warns against a "top-down engineering-driven" vision of "smart cities" where ICTs and "data-rich models... might be harnessed by technocrats in places like China or Singapore to further tighten their grip on how cities function", preferring the alternative vision where "smart cities" involve more social and inclusive processes of grassroots innovations working with government and industry. The social focus is echoed by Sennett (2012), who cautions against a "machine city" that "can deaden and stupefy the people who live in its all-efficient embrace", and instead argues for cities where inhabitants have a "more open, indeterminate city in which to make their way... (to) take ownership over their lives".

Haque (2012) critiques that 'smart' strategies should focus not on "the city as a single entity" but rather on 'the smartness of its citizens'. He views citizens as "generators of ideas, services and solutions, rather than subservient and passive recipients of them" and that cities should hence foster and facilitate their citizens' efforts, for example, through making data openly available. Hoornweg (2011), from a pragmatic perspective, stresses that the number one "smart" thing for cities is to "ensure good communication between government and citizens", and to "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. Robinson (2012) terms "leadership and

governance", "innovation forums", and "networks and community organizations" as the "soft infrastructure" necessary component of a "smart city".

Theory C - Cities that Learn, Relearn and Adapt

Assumptions: The "smart city" learns, relearns and adapts itself, through learning networks, as well as using metrics, monitoring and feedback processes.

Under this theory, a number of 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 city governance and management, and converting such learning to innovative application. City and institutional networks have been set up to facilitate this purpose, for example, Smart Cities supported by the European Regional Development Fund (www.smartcities.info), European Smart Cities which outlines a model for "smart cities" and shows benchmarking results (www.smart-cities.eu), the European Initiative on Smart Cities (setis.ec.europa.eu) etc. Cities and their planning organizations have the capability to learn, and with the aid of ICTs, may even extend their potential to incorporate double loops for re-learning and adaptation.

Implicit in the process of learning and re-learning is the ability to assess performance, in particular, through metrics or performance indicators defined according to a city's goals. For example, cities may have greenhouse gas emissions (GHGe) reduction targets or health and well-being indicators for their citizens. Cohen (2012), in his web articles, developed the "Smart Cities Wheel" rubric, which includes more than 100 indicators grouped into six broad categories of "Smart Economy", "Smart Environment", "Smart Governance", "Smart Living", "Smart Mobility" and "Smart People". He intends it to be a framework "that allow(s) a common language to develop amongst citizens, city staff, mayors, and the private sector" as cities track their performance and progress towards their goals, and adapt their policies and plans accordingly (Cohen 2012). Walters (2012) describes the interconnected processes of monitoring, managing and using gathered data for future simulations and design as "virtuous cycles in city planning and operation" that lead to more innovative solutions.

Theory D - Investing for the future

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

Another group of theorists frame "smart cities" from a business perspective. Kotkin (2009) expands the definition of "smart cities" beyond an environmentally

sustainable agenda involving infrastructure and livability, to include economic sustainability built on "economic fundamentals" and "savvy business and development decisions". Caragliu et al (2009), from their analysis of the performance of 70 European cities, emphasize the need for cities to focus on their stocks of capital, i.e. human, social and physical infrastructure:

> *"We believe 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."*

Kuk & Janssen (2011) examined the business models of two Dutch "smart cities", vis-à-vis their use of technology in providing or enhancing city services. They found that the design of the underlying information architecture, influenced by the cities' technological capabilities and resources, played a major role in how the cities could further create, innovate or improve city business processes in the long term.

A 2011 report by The Climate Group, Arup, Accenture & Horizon highlighted the potential for cities to "realize" savings and value through "smart" applications. For example, they quoted findings by Booz & Co. that "$22 trillion invested today in ICT to improve building and transportation efficiency would save cities $33 trillion and reduce future emissions by as much as 50% (The Climate Group et al 2011). This will require cities to first articulate their values and measures, and to create new business models (e.g. new revenue streams from city technology services, monetizing societal outcomes, leveraging the procurement power of the public sector, etc.). The report also urges cities to understand the total value chain involved in "smart cities" applications, so as to capture positive externalities from these "smart" assets, for example, through creating new markets by opening up data sources for ICT development.

The above raises a few important points; 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 the 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.

Chapter 3 – Case Analysis

To address the research question, 6 "smart cities" were chosen as case studies:

- Boston, Massachusetts, U.S.A.;
- San Francisco, U.S.A;
- Amsterdam, Netherlands;
- Stockholm, Sweden;
- Singapore; and
- Rio de Janeiro, Brazil.

Selection of Case Studies

A number of key selection criteria were applied in considering their selection:

a. *Close relevance or possible extension of application to urban planning*: While the broad nature of planning encompasses fields as wide-ranging as transportation and infrastructure planning, community engagement, citizen participation, etc., an important selection criteria will be to assess how the application of ICTs or new technologies may have closest relevance, or may be extended in application, to urban planning (e.g. landuse planning, development growth strategies, etc.). For example, a city with a "smart" initiative in transportation planning and management will be selected over a city with a "smart" initiative in electronic health records;

b. *Concrete initiatives*: Given the range of "smart" initiatives, the second criteria for the purpose of this research will be to select cities with initiatives that are already concrete, either having been already implemented or is in the course of being implemented. For example, cities which have initiatives that have been clearly identified, in partnership with technology providers, will be favored over cities which currently only have notions of application. This will allow better insight into challenges or learning points faced by the city planners, as well as functional or organizational issues that have arisen in relation to implementation;

c. *Breadth of application and initiatives*: Cities that have a breadth of application - i.e. initiatives in multiple fields – will be favored, as a wide range of application reflects a potentially broader concept of being "smart";

d. *Variety of political socio-economic contexts*: Fourth, the case studies will be chosen from a variety of political socio-economic contexts, as this may reflect how planners' perceptions or conceptualizations of "smart cities" may vary or be similar across different contexts;

e. *Innovative application*: Selecting cities with innovative applications will likely be interesting in drawing learning points on how boundaries are creatively pushed as part of being "smart", providing possible insightful inspiration for other cities; and

f. *Different technology providers*: Finally, selecting cities that work with different technology providers will potentially provide a broader insight into planners' perceptions or conceptualizations of "smart cities". Hence, choosing a variety of cities and technology providers will be better than selecting a number of cities who rely on a single technology provider.

Selected Cities: Different Contexts

While the unit of analysis for this study is the city, it must be noted that the selected cities differ in terms of their scales and sizes, their contexts of governance, modes of city planning, management and operations, etc. For example, the efforts described for the City of Boston do not extend to surrounding municipalities within the Greater Boston metropolitan area; larger scale issues such as transportation planning do not fall directly under the City's purview but are undertaken together with other organizations like the Boston Region Metropolitan Planning Organization (MPO). For Rio de Janeiro, the study refers to the Prefecture, while for Singapore, the entire city-state is considered given its single-tier government. In addition, the cities differ in terms of scale and size. The Cities of Boston and Stockholm have relatively smaller populations of 0.63 million (U.S. Census Bureau 2013) and 0.85 million (City of Stockholm 2012a) excluding their metropolitan regions, while Rio de Janeiro and Singapore have populations of 6.32 million (Brazilian Institute of Geography & Statistics 2013) and 5.31 million (Department of Statistics Singapore 2013), respectively. As such, this study was mindful that like-for-like comparisons are not feasible; instead, the approaches taken by the cities are examined in light of their own contexts.

Data Collection: Key City Agencies and Representatives

From the cities selected, a number of key city agencies / departments directly involved in the conceptualization and implementation of "smart" initiatives, including the application of ICTs, were chosen (see Appendix 2). In general, these city agencies / departments are also the ones leading the setting of visions and goals involved, with a high level of understanding of ICTs and engagement with technology providers. Representatives from these agencies / departments were contacted, and phone and email interviews were conducted based on the interview questionnaire shown in Appendix 3.

For some of the city agencies / departments where interviews could not be arranged, this study relied on secondary data sources including news articles, blog

articles, city reports, papers and presentations. It is noted here that many of these data sources are non-academic in nature, and as such, may provide a different perspective and level of analysis on the cities' efforts; for example, some news or blog articles may not have involved a systematic research-based data collection process. In addition, reports and presentations that originate from the cities and technology providers may offer a specific viewpoint that reflect their own interests in their "smart" efforts; for example, it will be difficult to imagine a technology provider being critical of its own systems and weaknesses. For many of the "smart" initiatives, there were limited data on their effectiveness. As such, the examples of initiatives presented in this paper are based more on their noteworthiness rather than success.

For Rio de Janeiro, despite some correspondence and a number of efforts to contact several city officials, however, interviews could not be arranged. Notwithstanding the lack of primary data sources, it was important to include Rio de Janeiro in this study and to examine its efforts. This is given the city's high profile and widely quoted example as a "smart" city with a uniquely integrated city operations center, to gain a broader perspective for this study.

Boston, Massachusetts, U.S.A.

"Smart" city concept

Based on Cohen's "Smart Cities Wheel", Boston is ranked as the top 'smartest city' in North America[3]. Cohen attributes this to the city's entrepreneurial and innovation ecosystem, in particular, the Mayor's Office for New Urban Mechanics (MONUM), as well as its concentration of "some of the smartest people in the world", and that "Boston is home to more than 70 universities and colleges, eight of which are dedicated research universities with $1.5 billion in annual R&D expenditures" (Cohen 2012b). Based on another methodology focused on education and intellectual environment[4], Boston was also ranked the "smartest" out of America's 55 large cities (The Daily Beast, 2010).

According to Osgood (2013), the city's "smart" efforts focus on the use of technology and design to be more engaging to its citizens and to address their concerns. The

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[3] Cohen's "Smart Cities Wheel" North America ranking is based on data from the Brookings Institute Global Metro Monitor and Ocean Tomo's Inventive Cities (Smart Economy), Siemens Green City Index, Clean Tech Index and Corporate Knights' Canadian Sustainable Cities (Smart Environment), E-Governance Institute's 2011 rankings, Data Catalogs, Digital Cities Survey (Smart Governance), Mercer Quality of Living report (Smart Living), Walkscore, Siemens Transit Rankings, Canadian Public Transit Accessibility and U.S. Census (Smart Mobility), and The Economist Global Competitiveness Rankings (Smart People).

[4] The Daily Beast ranked cities based on education criteria like percentage of residents over age 25 with bachelor's and graduate degrees, and intellectual environment indicators such as amount of non-fiction book sales, number of institutions of higher education, and number of libraries per capita.

city takes a hands-on, people-focused approach that is reflected in MONUM's name, as coined after mayor Thomas Menino:

> *"Sixteen years ago I was labeled the Urban Mechanic and described as a sort of one-man 'Mr. Fix-It' when it came to the basics that make our city work. The nickname was overstated then, but it's outdated now – we are all urban mechanics."* - City of Boston Mayor Thomas Menino (MONUM 2013).

Osgood highlighted that compared to other cities, MONUM's work for the city takes less of a 'big data' approach, but instead, relies on small incremental prototypes that are developed jointly with line agencies, tested and scaled up. MONUM's set up is also not that of a separate 'skunkworks' laboratory, but instead, closely integrated with city departments. MONUM "smart" initiatives are focused on three main areas, "Participatory Urbanism", "Clicks & Bricks" and "Education" (MONUM 2013). Besides these, other agencies within the City, in particular the Department of Innovation and Technology (DoIT), have also embarked on other initiatives such as an open government portal, open data cloud, encouraging digital literacy, as well as collaborations with technology providers like IBM on its "Smarter Cities Challenge". Boston's southern waterfront is also branded as the "Innovation District".

Examples of "Smart" Initiatives

Participatory Urbanism

Under "Participatory Urbanism", MONUM aims to engage citizens and forge "closer connection and communication between City government and its citizens", and to "leverage... new technology and civic spirit to deliver services that are more personal and citizen-driven" (MONUM 2013).

The "Boston Citizens Connect" is an example of a participatory initiative, where citizens are engaged to "be the City's eyes and ears" (City of Boston 2013a). Through the use of mobile apps, a website, Twitter, or SMS, citizens are able to report issues such as potholes, graffiti, fallen trees, requests for snow plowing, etc., from anywhere in the city. The reports, which are geo-located, include data fields for citizens to describe the problem or situation, as well as submit a photograph. Each report, which "opens" a city work order requiring action, is assigned a case identification number and can be viewed as a list or on a map. For example, after a heavy snowstorm in February 2013, the Citizens Connect website and app listed reports requesting for snow shoveling along sidewalks (see Figure 1 and Figure 2). After each case is addressed as by the city's service teams and the situation resolved, the case is closed and remarks from city workers are reported (see Figure 3).

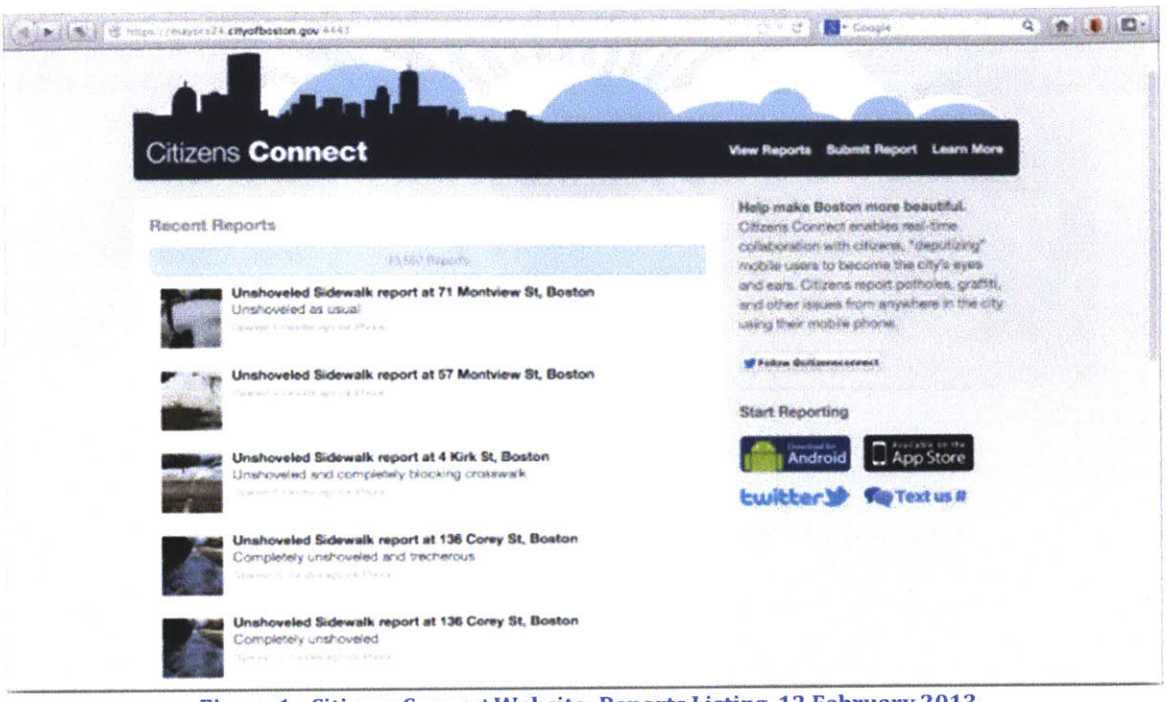

Figure 1 - Citizens Connect Website: Reports Listing, 12 February 2013
Source: https://mayors24.cityofboston.gov:4443/

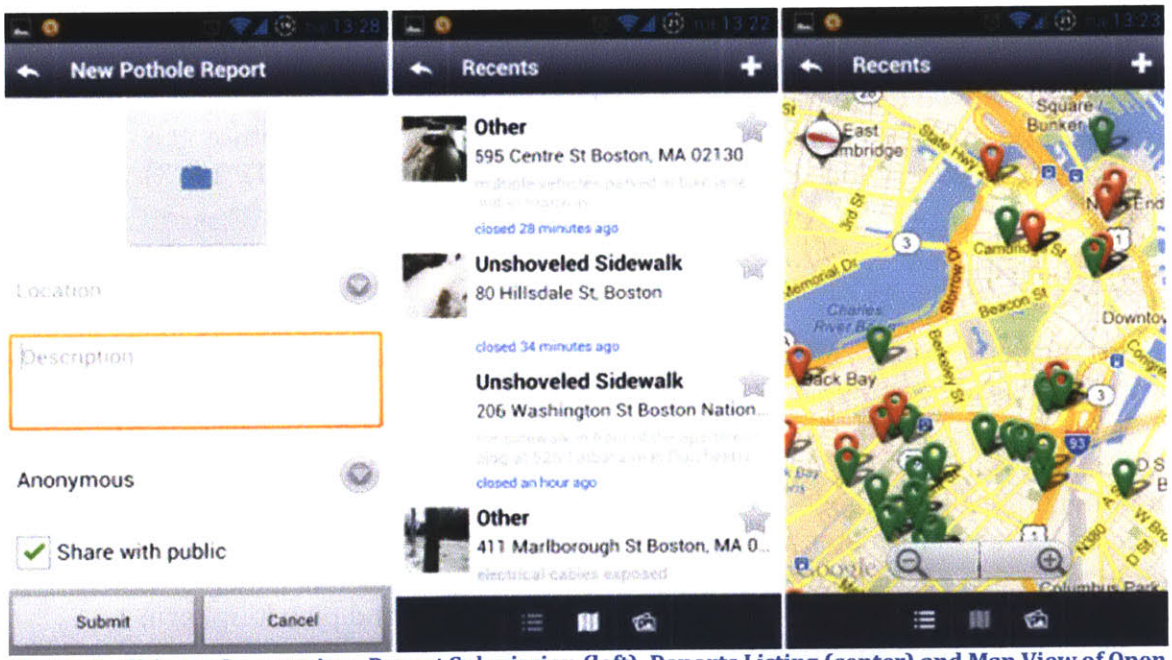

Figure 2 - Citizens Connect App: Report Submission (left), Reports Listing (center) and Map View of Open Reports in red and Resolved Cases in green (right), 12 February 2013

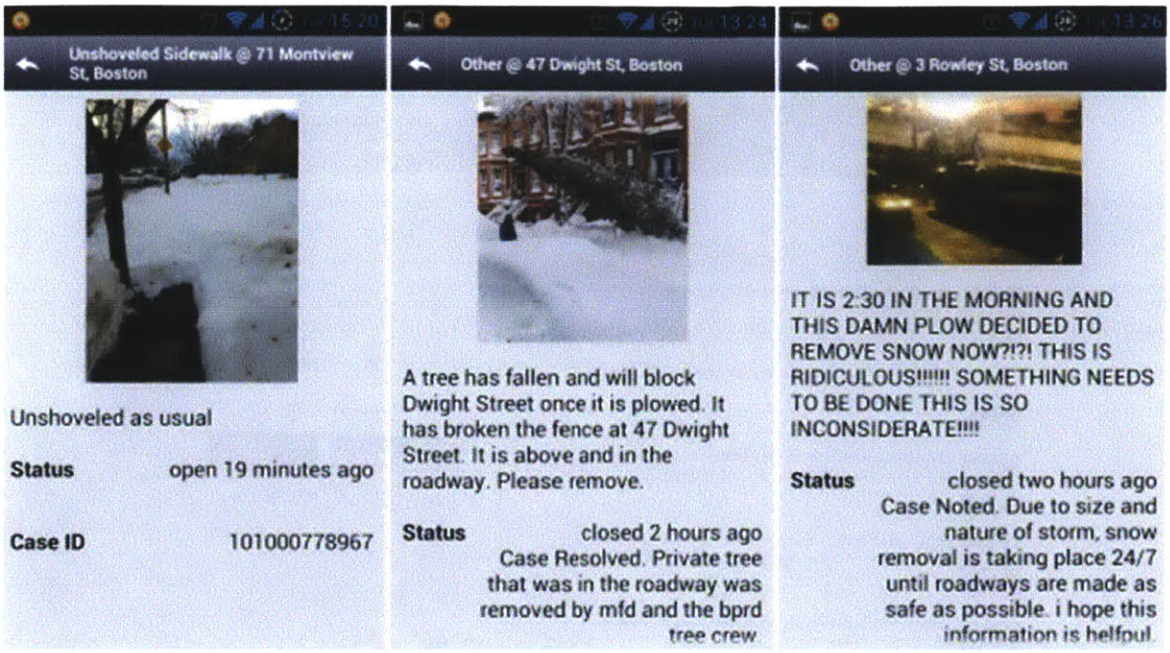

Figure 3 - Citizens Connect App: Open Report (left) and Resolved Cases (center and right), 12 February 2013

In another participatory initiative held in 2011, MONUM collaborated with the Boston Public Schools (BPS) to use "Community PlanIT", an engagement game platform developed by the Engagement Game Lab at Emerson College, to gather community feedback on a school performance metrics and accountability system. The game involved teachers, students, parents and administrators, who produced a total of more than 4,600 online comments, and who also came together at a community meeting which collated the feedback (Community PlanIT 2013).

Clicks & Bricks

Under "Clicks & Bricks", MONUM focuses on technology infrastructure and sustainable design in the City's management of its built environment.

One "smart" initiative is "Street Bump", a mobile app that "helps residents improve their neighborhood streets" (MONUM 2013). The app uses sensors in mobile devices - i.e. accelerometer and GPS – to record the location of uneven surfaces while users drive (see Figure 4). MONUM's objective is that "the data provides governments with real-time information to fix problems and plan long term investments" (Street Bump 2013).

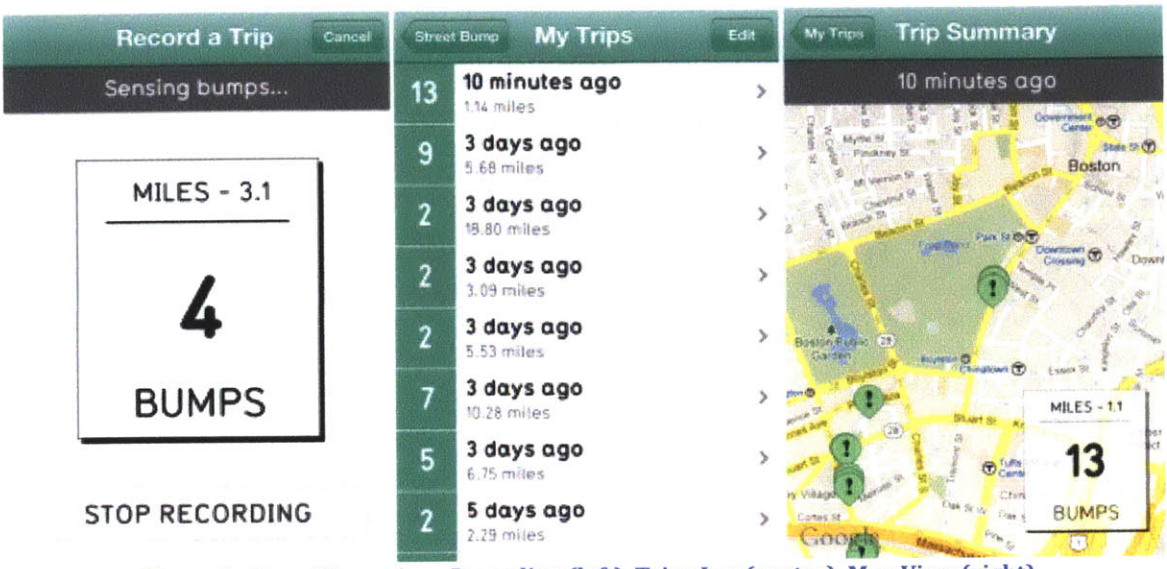

Figure 4 - Street Bump App: Recording (left), Trips Log (center), Map View (right)
Source: http://streetbump.org/about

Another initiative is the in-house "City Worker" app, which was developed for city workers to manage and address citizen requests for city services in a real-time manner – e.g. the cases received through Citizens Connect - and to create new work orders (see Figure 5).

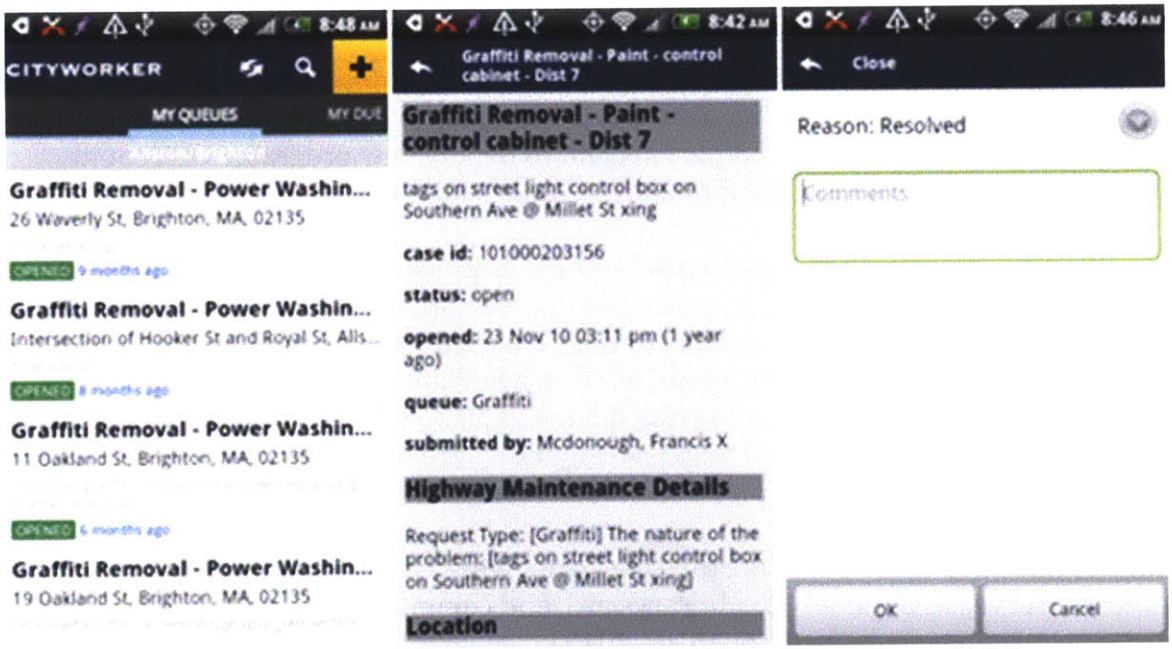

Figure 5 - City Worker App: Cases Queue (left), Issue (center), Response (right).
Source: http://www.cityofboston.gov/doit/initiatives/applications.asp

The "Adopt-a-Hydrant" project was developed in collaboration with Code for America, for residents to voluntarily adopt hydrants that they will shovel out after snowstorms. In see Figure 6, adopted hydrants are shown in green and include the names of the residents.

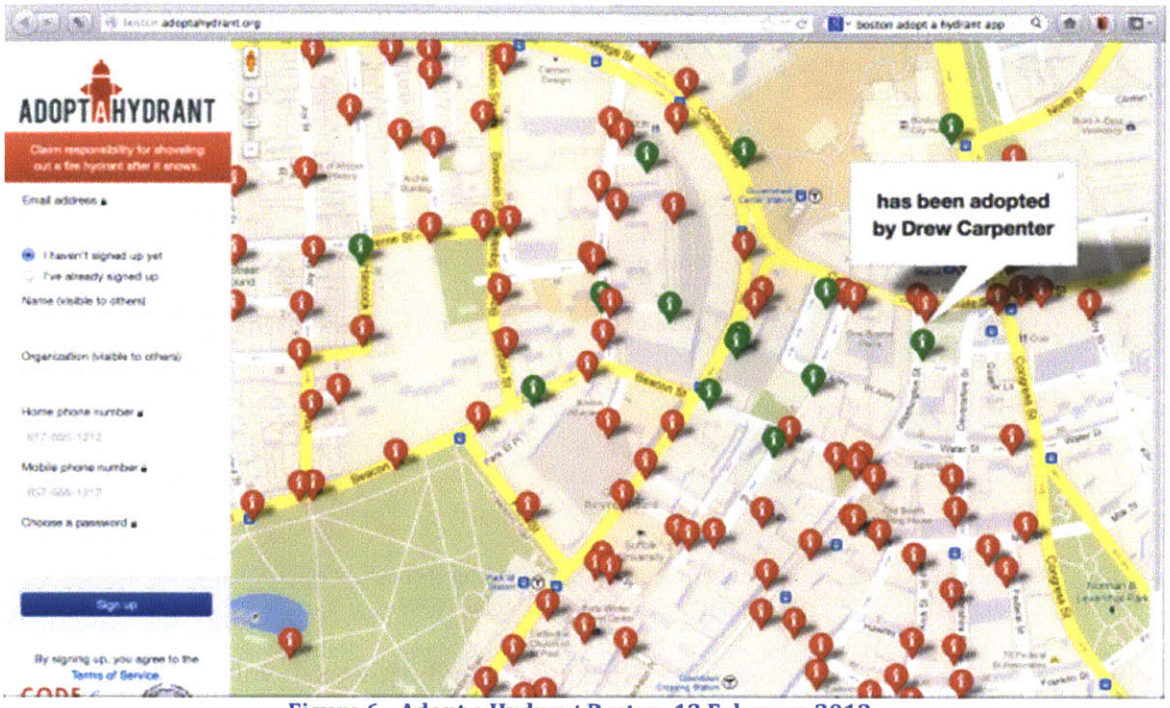

Figure 6 - Adopt a Hydrant Boston, 13 February 2013.
Source: http://boston.adoptahydrant.org/

Education

Under "Education", MONUM collaborates with schools, community centers and libraries to explore "the use of new tools and technology to facilitate communication between educators, students and parents and to deploy new programs that could improve offerings both inside and outside schools" (MONUM 2013).

One initiative, developed together with Code for America, is "Discover BPS (Boston Public Schools)". MONUM (2013) describes this web app to help parents "navigate the options of public schools available to their children", and includes tools to map and access more details on the schools, as shown in Figure 7. A related initiative undertaken by DoIT with BPS is "Boston School Choice", where different models and tools, such as a interactive zonal map (see Figure 8), are being explored to help improve the existing school choice and student assignment system.

Another initiative is the pilot "Boston One Card", where a single card for BPS students "serves as a school ID, a library card, and community center membership card, as well as a transit pass" (MONUM 2013).

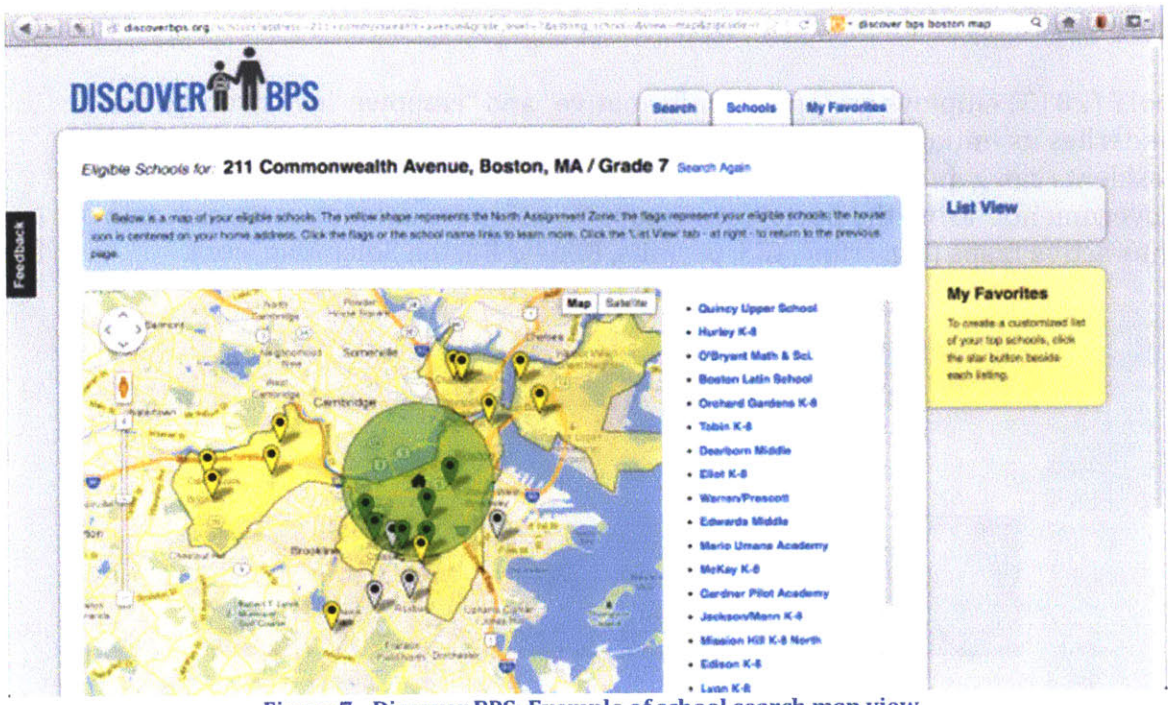

Figure 7 - Discover BPS: Example of school search map view
Source: http://discoverbps.org/schools

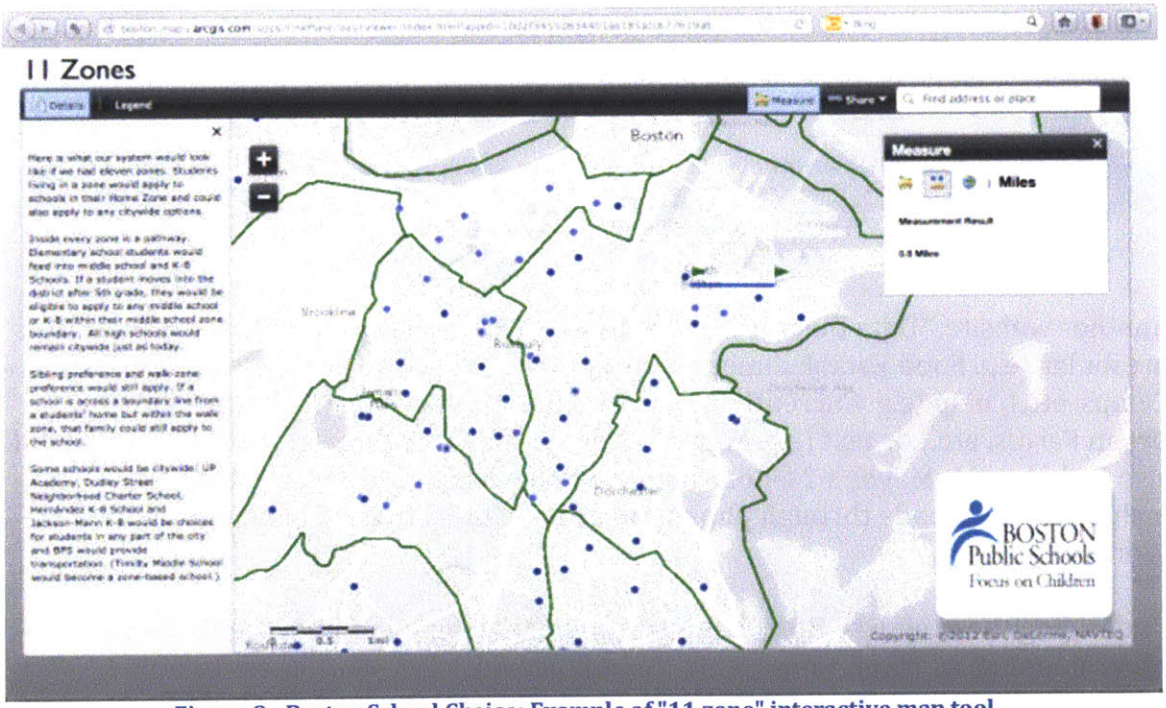

Figure 8 - Boston School Choice: Example of "11 zone" interactive map tool.
Source: http://boston.maps.arcgis.com/apps/OnePane/basicviewer/index.html

Open Government Portal & Open Data

DoIT (2013) employs an "open", "informative" and "empowering" strategy that underlies its initiatives. It recently launched its "Open Government Portal", where residents can gain "better access to the performance, processes and people of City government". From the portal (see Figure 9), users are able to access city data on interactive maps (e.g. crime, GIS, permits, Renew Boston Solar Map, etc.).

Figure 9 - City of Boston Open Government Portal
Source: http://www.cityofboston.gov/open/

Another website, "Data Boston", serves as a "warehouse" for more than fifty datasets in tabular (e.g. Food Establishment Inspections, Children's Feeding Program, Day Camps, etc.), map (e.g. Currently Active Building Permits, Healthy Corner Stores, Urban Farms, etc.) or text (e.g. Mayor's State of the City Address) format. This portal also includes the Mayor's 24-hour hotline, which lists the status of citizen requests including those made through phone call or from the Citizens Connect or City Worker apps.

Underlying these efforts, Boston is also supporting digital literacy and training programs such as "Tech Goes Home", which provides low-cost access to home internet and a netbook or mobile device, and partnering with schools and communities to provide training.

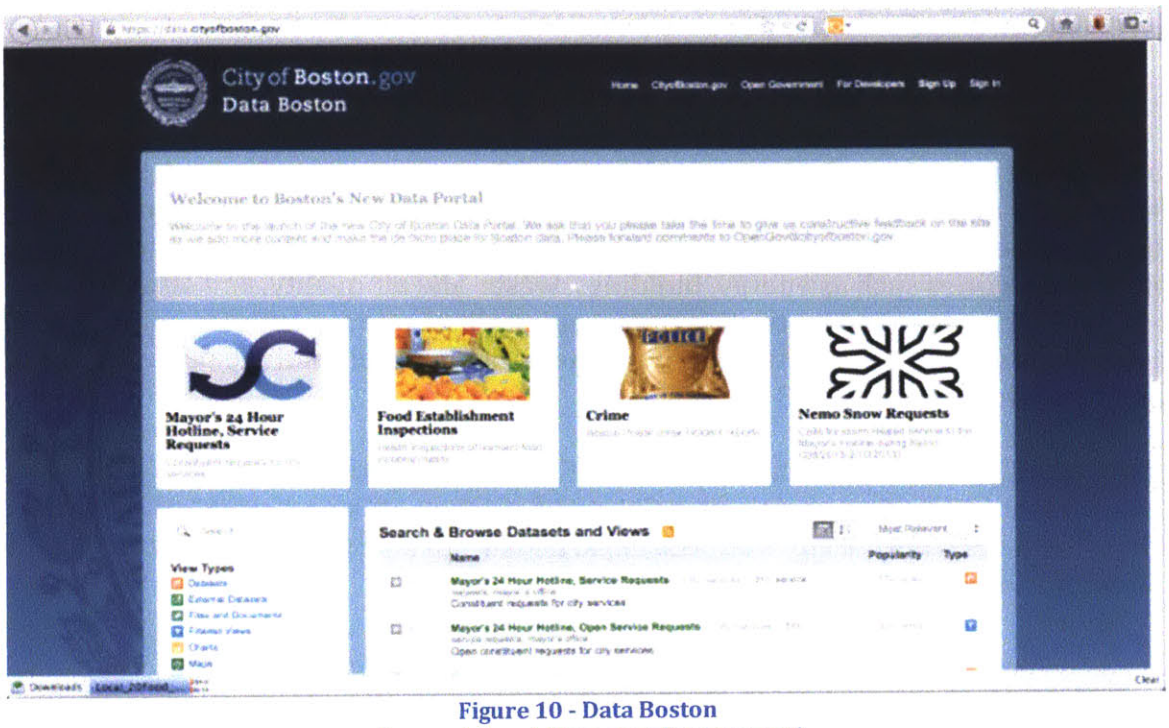

Figure 10 - Data Boston
Source: https://data.cityofboston.gov/

IBM Smarter Cities Challenge: Transportation

In 2012, Boston collaborated with IBM and Boston University, as part of the IBM Smarter Cities Challenge, to explore ways to see how data from the city's video cameras, street sensors and databases, as well as sources such as citizens' mobile phone accelerometer data and comments made on social media can be used to provide a real-time picture of the traffic situation (Dillow 2012). Aware of the potential that the algorithmic analysis of combined data can help the city "redesign traffic flows" and "cut vehicle emissions by letting the city know where cars constantly idle in traffic" (Farrell 2012), the city is currently assessing how a pilot system can be implemented.

Innovation District

Boston branded its south waterfront as the "Innovation District", which will "allow for the testing of groundbreaking technologies in clean energy, citizen participation, transportation, and city infrastructure" (City of Boston 2013). The district is envisaged to be a "hub for emerging ideas and a development space to create new best practices", catering to both smaller start ups and larger firms, providing a range of flexible housing options "to fit the range of lifestyles and needs of the innovation workforce" and having public space and programming to "foster an innovation ecosystem".

San Francisco, U.S.A

"Smart" city concept

Cohen (2012) ranks San Francisco as the second "smartest city" in North America. He notes the city's vibrancy and "thriving entrepreneurial economy". Cohen highlights the city's efforts in environmental leadership, where the city is highly rated in categories such as energy, buildings, waste, and air quality, and also cites the city as being home to innovative organizations like Code for America, which "helps governments work better for everyone with the people and the power of the web" (Code for America 2013).

Miller (2013), a spokesperson from the San Francisco Department of the Environment (SF Environment), cites Cohens' definition of "smart cities" as the concept and basis for the city's efforts, in particular, "to take (our) sustainability operations to the next level":

> *"...smart cities use information and communication technologies to be more intelligent and efficient in the use of resources, resulting in cost and energy savings, improved service delivery and quality of life, and reduced environmental footprint – all supporting innovation and the low-carbon economy."*

SF Environment sees the use of technology to "thread together the building, transportation and the energy sectors" to help achieve the "triple bottom line of protecting the environment, expanding economic opportunities, and increasing livability". The use of ICTs is evident in many of SF Environment's initiatives, which aim to advance the city's sustainability goals, including "RecycleWhere", "Zero Waste Signmaker", "SF Energy Map", "Energy Use Challenge", "Honest Buildings" and "ChargePoint" (SF Environment 2013). Nutter (2012) summarizes the importance of "smart" initiatives to meet the city's sustainability objectives:

> *"In San Francisco, we do believe that smart city solutions enable further progress on sustainability and our sustainability goals will need to rely on smart city solutions to succeed."*

The city also encourages innovation and the use of open data, with initiatives such as "DataSF", "Improve SF", "Business One-Stop", hackathons, etc., led by city departments such as the Mayor's Office of Civic Innovation (MOCI) and Department of Technology, and partners from the community and public and private organizations. Underlying MOCI's efforts, according to Jay Nath, the city's Chief Innovation Officer, is the belief in the "amazing opportunity to harness the creativity and intelligence of our community to disrupt traditional areas that have been resistant to improvements" (City & County of San Francisco 2012a), and these efforts aim to help "create community-sourced solutions that improve the efficiency

and accessibility of government" (Feller 2012). Nath (2012) emphasizes the need for experimentation within government:

> *"Government is built for continuity, sustainability. It's not really built for risk-taking. You wouldn't want them to take risks. Having a sandbox where we can actually do some experimentation and take on high-impact projects and take on higher-risk projects is really important".*

The city's emphasis on innovation, as well as the city government's openness to experimentation, is underscored by Mayor Edwin Lee (2012), who also declared October as the "Innovation Month" for the city:

> *"... Innovation is a key driver to the way we run government, the way we improve government, and the way we collaborate... we have to have government let go of the way that they've been doing things. I've been letting go for some period of time when I realized that the government wasn't the creator of the best ideas... I think that the role of government now is really more of a convenor..."*

Examples of "Smart" Initiatives

Reducing Greenhouse Gas (GHGe) Emissions

San Francisco targets to become carbon-free by 2030 and is "implementing a comprehensive suite of incentive programs to improve the performance of new and existing buildings" (SF Environment 2013). An example of an initiative to encourage the use of renewable energy is "SF Energy Map", which visualizes clean energy activity in the city including the locations of buildings with solar installations and notable case studies, as well as letting users calculate the solar potential for their properties (see Figure 11), a wind resource map which reflects the average wind speed throughout the city (see Figure 12), as well as links to resources that help users estimate photovoltaic (PV) power and water heating system sizes and costs. Another initiative is the partnership with "Honest Buildings", an online information-sharing network on building performance and energy-efficiency strategies. The city also recently passed its "Existing Commercial Building Ordinance", which requires all commercial buildings with more than 10,000 sq ft to benchmark and report its energy usage data to the city, with the intention that "having open data and transparency... will help property owners and property managers take action once they see where there're inefficiencies in their buildings" (Nutter 2012).

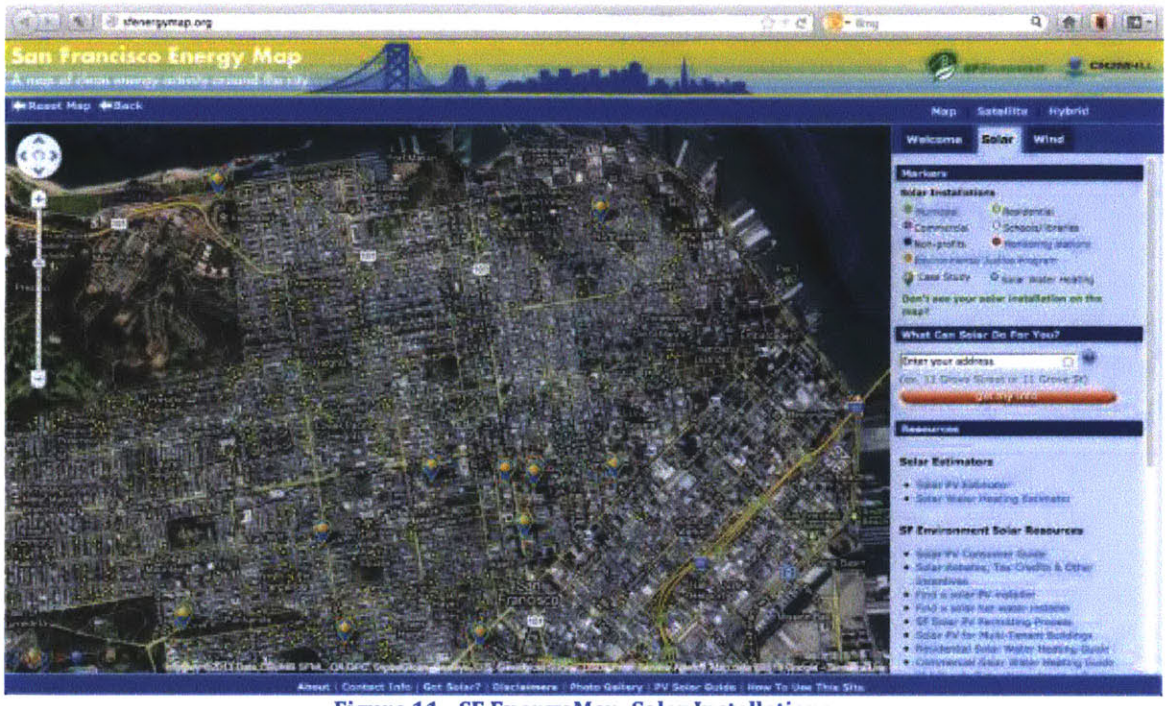

Figure 11 - SF Energy Map: Solar Installations
Source: http://sfenergymap.org/

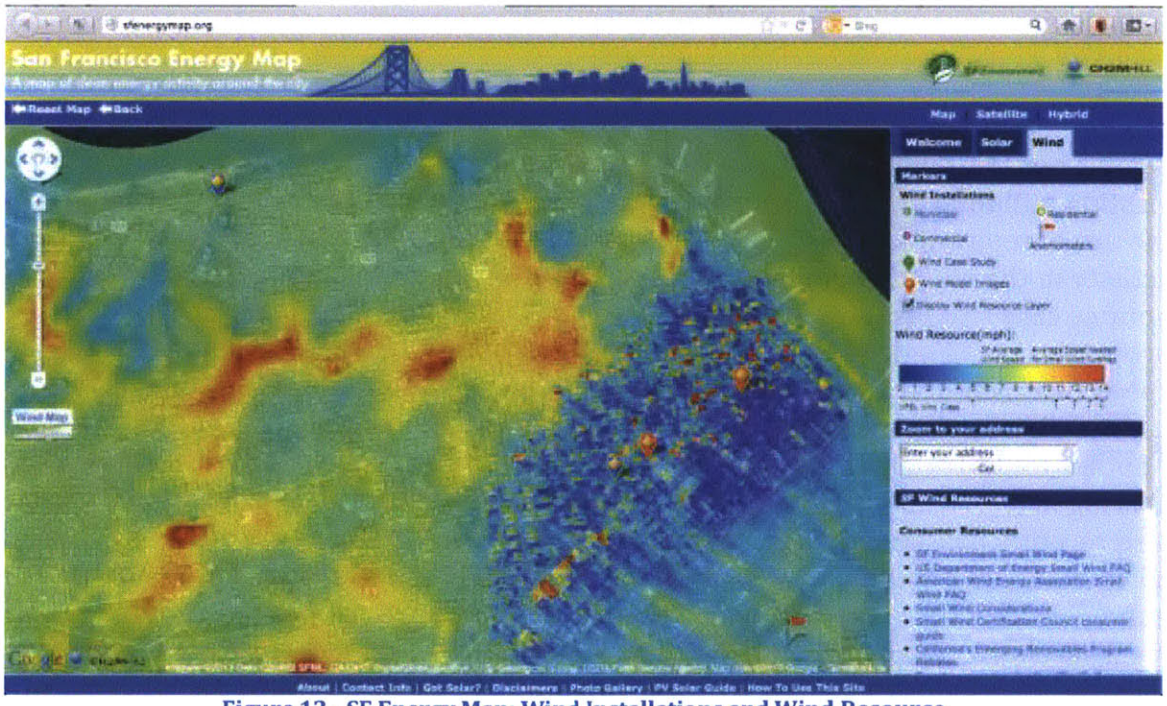

Figure 12 - SF Energy Map: Wind Installations and Wind Resource
Source: http://sfenergymap.org/

In terms of transportation, SF Environment uses the "ChargePoint" network, a web and mobile app which maps and tracks usage of status of 110 public electric vehicle (EV) charging stations around the city (SF Environment 2012). Another initiative,

"SF park", collects and distributes real-time information on parking availability around the city, while adjusting parking rates to match demand (SF Park 2013).

Reducing Waste

To help the city meet its 2020 zero waste target, SF Environment implemented the "RecycleWhere" initiative which provides information on recycling, reuse and waste disposal options. For example, a search for the disposal of a working television will yield alerts prompting the user to consider reusing / donating the functional used item, a warning that it is illegal to put electronics into the garbage can, as well as a list of drop-off locations based on the user's address (see Figure 13).

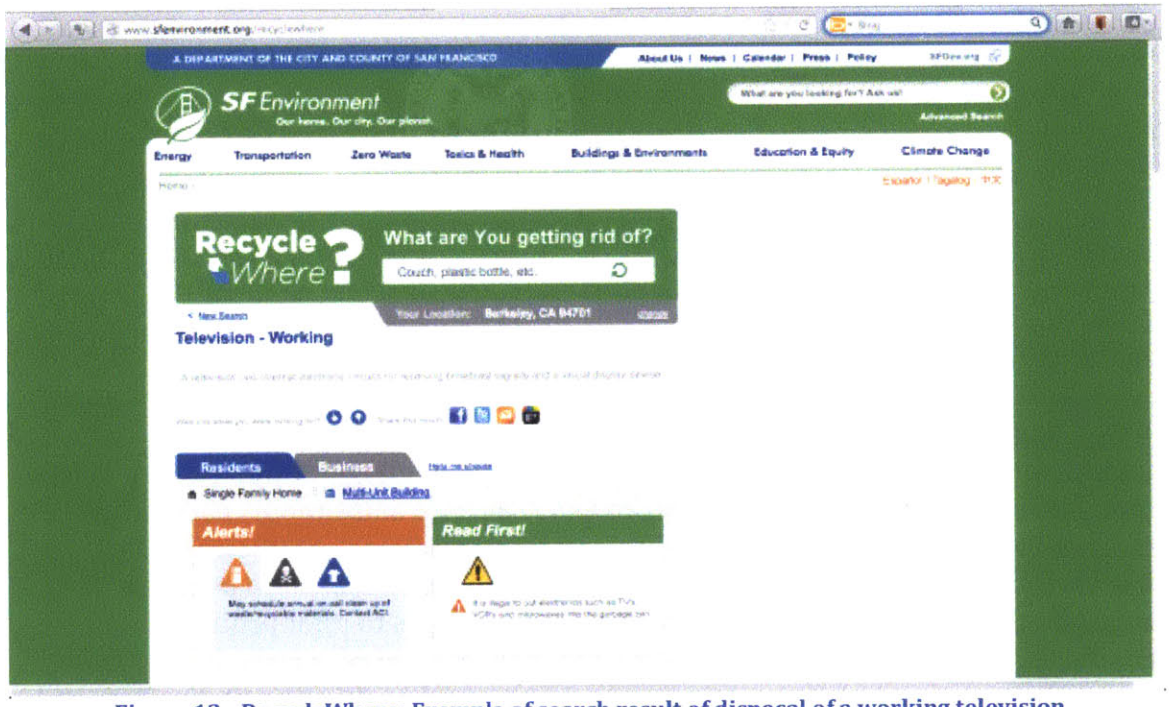

Figure 13 - RecycleWhere: Example of search result of disposal of a working television
Source: http://www.sfenvironment.org/recyclewhere

The "Zero Waste Signmaker" website features a simple drag-and-drop application allowing users to make and download their own compost, recycling and landfill signs with customizable graphics and text (see Figure 14).

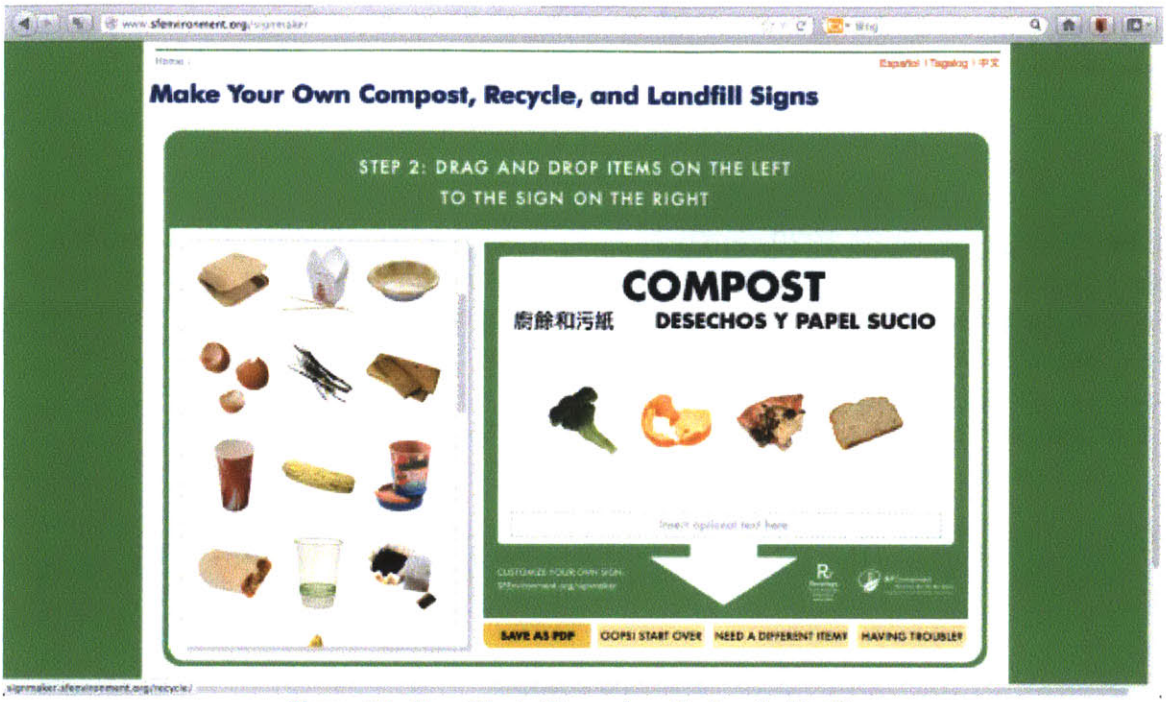

Figure 14 - Zero Waste Signmaker: Customizable Sign
Source: http://www.sfenvironment.org/signmaker

CleantechSF and Living Innovation Zones

In 2012, San Francisco launched the "CleantechSF" initiative, which aims to "streamline the demonstration and testing of clean technologies utilizing City assets, attract cleantech anchoring institutions to San Francisco and support early stage cleantech firms in San Francisco" (City & County of San Francisco 2012b). The initiative includes identifying and using "Living Innovation Zones" to facilitate businesses to use city-owned properties and public assets to pilot products, technology and design concepts. Through the initiative, there is potential for these to "contribute to the city's economic development, neighborhood revitalization, and sustainable operations" (SFEnvironment 2013).

InnovateSF

The InnovateSF portal run by MOCI, features projects based on its three strategic focus areas in "economic development, citizen engagement and government efficiency" (InnovateSF 2013a). For example, the city recently launched the "License 123" tool that provides information on city, county, state and federal permit and license forms (see Figure 15).

Figure 15 - License123
Source: http://sf.license123.com/

Another initiative, the "Startup Map" (see Figure 16), is used as "a platform to show how much funding is coming in to SF startups, where jobs are and much much more", allowing local businesses to add their company details and "be a part of the story of San Francisco as the best place to live, work and play" (InnovateSF 2013b).

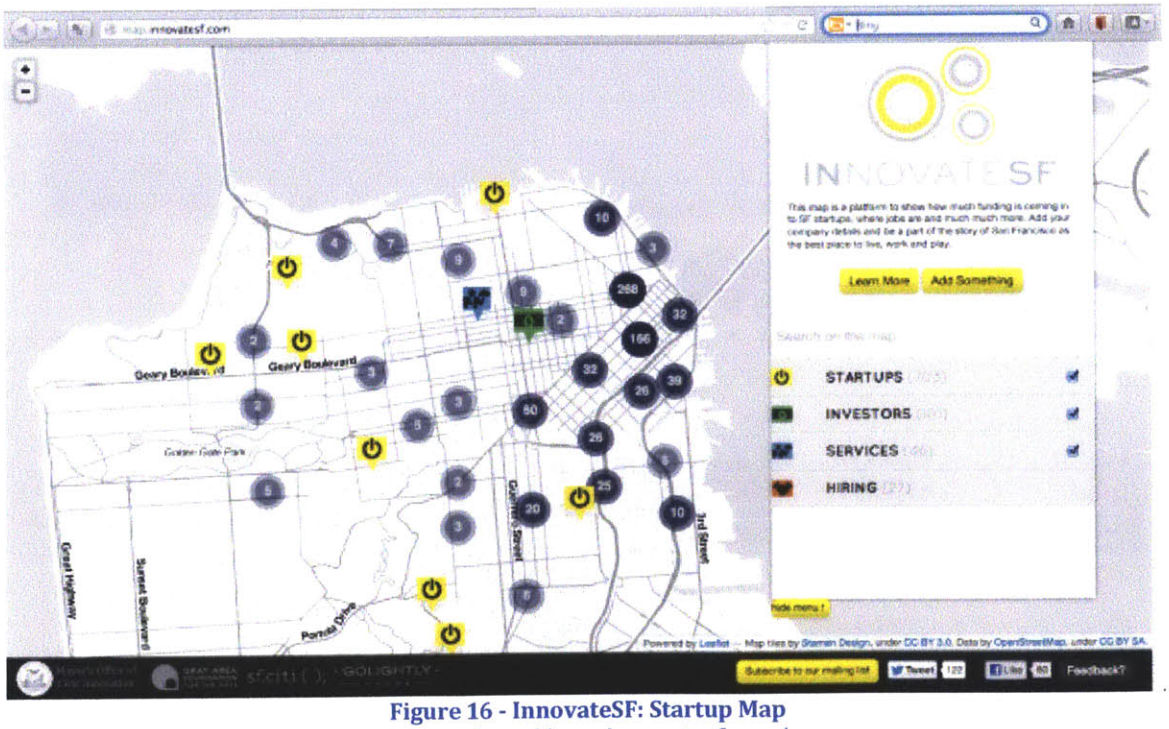

Figure 16 - InnovateSF: Startup Map
Source: http://map.innovatesf.com/

Open Data and DataSF

As the first city in the U.S. to enact open data legislation in 2009, San Francisco's Open Data policy aims to make its city government "open and accessible":

> *"An open data policy provides numerous benefits for both government and the public, such as enhanced government transparency and accountability, development of new analyses, applications, and civic tools based on City data, increased civic engagement, social and economic benefits as a result of innovative resident interaction with government, empowerment of citizens through democratization of information, increased government efficiency and delivery of services, and more."* (InnovateSF 2013)

In 2012, the city proposed revisions to the legislation, "creating the position of Chief Data Officer and Department Data Coordinators to implement the standards and policies articulated in the City's Open Data Policy" (San Francisco City Attorney 2012). The DataSF data portal (see Figure 17) contains more than 500 datasets available in tabular, map, calendar and chart formats, including popularly accessed ones such as Crime Incidents, Case Data from San Francisco 311, Film Locations, Building Footprints, Planning Neighborhoods etc., as well as a showcase of apps developed using its datasets (DataSF 2013).

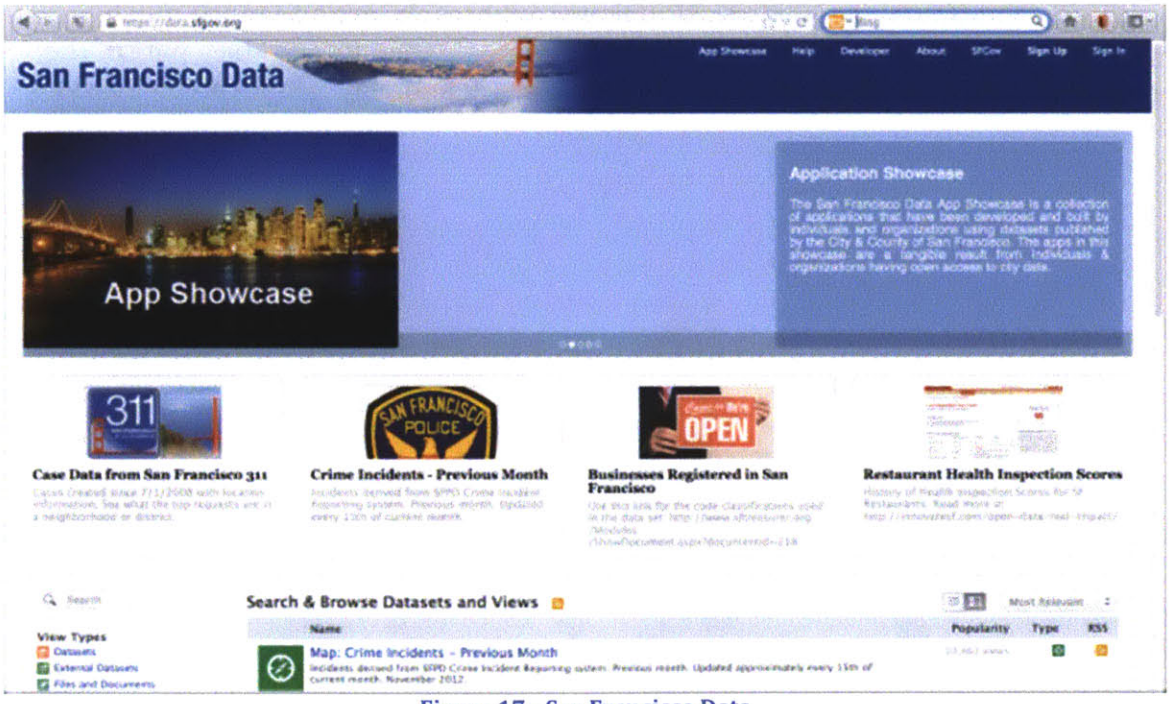

Figure 17 - San Francisco Data
Source: https://data.sfgov.org/

Idea-generating Platforms: ImproveSF and Hackathons

"ImproveSF" (see Figure 18) is "an online platform to provide opportunities for government and citizens to work together by connecting civic challenges to community problem-solvers" (ImproveSF 2013). Challenges are identified by an organization or by the community, and are opened to members of the community to contribute ideas and comments. Contributors earn points, which can be exchanged for rewards. For example, 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 along these routes. In another example, ImproveSF collaborated with local community organizations to pose the challenge on how Central Market / Tenderloin residents can "prepare healthy food when their access to kitchen facilities is limited".

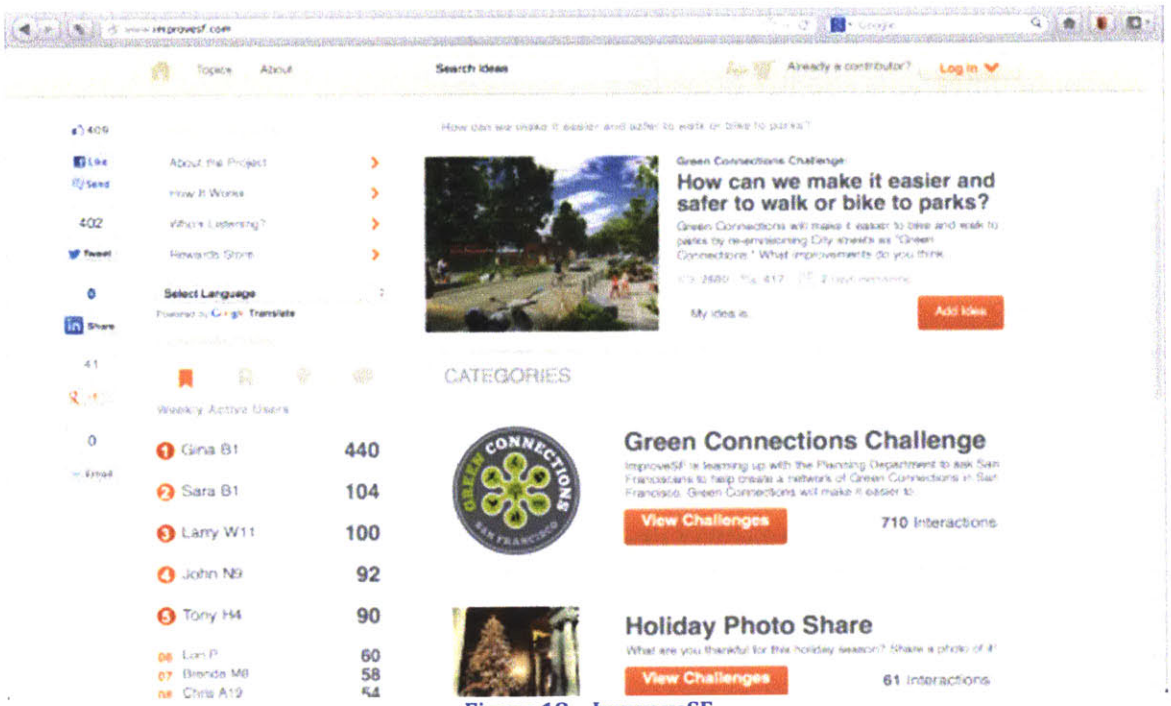

Figure 18 – ImproveSF
Source: http://www.improvesf.com/

Other idea-generating platforms include hackathons such as "Unhackathon" and "Summer of Smart", held by organizations in collaboration with city departments and community groups. For example, the "Unhackathon #1 Taxi!" challenge posed questions on how taxis may be better distributed with technology, while the "Unhackathon #2 Economic Opportunity" challenge focused on how design-driven technology could be used to "identify, encourage or spread small business growth" through the city (Mix & Stir 2013). From the 2011 three-month long "Summer of Smart" program organized by the Gray Area Foundation for the Arts (@GAFFTA), projects generated included "PublicArtSpaces" which matches under-used urban spaces with artists, the "Smart Muni" app which track the city's buses in real time and identifies incidents in the Muni transit system, and the "Market Guardians" app

which encourages crowdsourcing on the availability of healthy food (Schwartz 2011).

Amsterdam, Netherlands

"Smart" city concept

In its report on 'smart cities', The Economist (2012) newspaper contrasted the "problems" of several "top-down" projects - e.g. Masdar's delay in completion and lack of businesses and people moving in, Songdo City "a fancy real-estate project in search of a purpose", etc. – with the "bottom-up" approach of cities like Amsterdam which relies on a collaborative platform rather than a master plan. This platform, the Amsterdam Smart City (ASC) program, was initiated by the Amsterdam Innovation Motor (an independent organization promoting innovation, cooperation and new business), the City of Amsterdam, Liander (an energy company) and KPN (a telecommunications and ICT provider):

> *"Using a collective approach by bringing partners together and setting up local projects, ASC makes it possible to test new initiatives. The most effective initiatives can then be implemented on a larger scale. All the acquired knowledge and experience is shared via the ASC platform. In this way, ASC helps to accelerate climate and energy programmes. The ultimate goal of all activities is to contribute positively towards achieving CO2 emission targets, as well as aiding the economic development of the Amsterdam Metropolitan Area. In doing so, the quality of life will improve for everyone."* (Amsterdam Smart City 2013).

There are currently more than thirty initiatives implemented by over 70 partners. These are categorized by five themes – i.e. Living, Working, Mobility, Public facilities and Open data - and focused on three test-bedding locations, Nieuw West, Zuidoost and IJburg.

Examples of "Smart" Initiatives

Living

Recognizing that the 400,000 households in Amsterdam are responsible for "approximately one third of the total CO2 emissions" (Amsterdam Smart City 2013), a number of initiatives focus on "smart and energy-saving technologies" to reduce energy consumption and CO2 emissions. For example, in the "Geuzenveld Sustainable Neighborhood" initiative, more than 500 households were provided with smart meters that measure their energy consumption, as well as displays (see Figure 19) "which create a sense of awareness ... improve their behavior and thereby save energy" (Sustainable Living Geuzenveld 2010). Similarly, under the "Energy Management Haarlem" initiative, 250 households tested an energy

management system that tracked energy consumption and provided an online monitoring system (Amsterdam Smart City 2013). At West Orange, households piloted another energy management system connected to the digital gas and electricity meter, allowing users to turn appliances on or off remotely.

Figure 19 - Sustainable Living Geuzenveld: Energy Consumption Display
Source: http://www.youtube.com/watch?v=zrJQITGbfl4&feature=plcp

The "Ijburg You Decide" initiative is an "End User Driven Innovation" project, where residents are asked to contribute ideas and describe their issues regarding energy and mobility through a web questionnaire (Amsterdam Smart City 2013).

Almere, a growing city within the Amsterdam metropolitan area, has embarked on a collaborative effort to build a "smart society", through a collaborative partnership between its Almere Economic Development Board and a consortium involving technology providers Cisco, IBM, Liander, Living PlanIT and Philips:

> *"The Almere Smart Society vision involves the realization of an ICT facility which, amongst other things, will promote more efficient urban management, innovation and economic growth, strong social cohesion and sustainable development. The smart connections can also generate substantial cost savings in running the city. For example, the local urban management processes will be supported by an intelligent digital infrastructure for the exchange of information, services and applications between all municipal departments in areas, such as public safety, traffic and mobility, waste management and the coordination of relief efforts in the event of disruptions, incidents or disasters in the city."* (Amsterdam Smart City 2013).

For example, the partnership aims to pilot an "intelligent digital infrastructure" that will "connect individuals and public organizations and facilitate fast interaction and communication" in the neighborhoods of Waterwijk and Homeruskwartier (Living PlanIT 2012). This is in addition to existing "smart" applications in the city. These include the use of navigation devices in cars to analyze traffic flows, a supermarket which provides heat from its refrigeration to an adjacent apartment building (Almere Smart City 2013), waste bins that indicate the need for emptying and which reduce collection costs, a glass fiber communications network, the use of internet video communications in health care, and the use of CCTVs for security (Almere Smart Society 2012).

Working

The first "Smart Work Center" (SWC) was implemented by CISCO in Almere in 2008. As an office center equipped with workstations, CISCO TelePresence teleconference equipment, function rooms, a childcare center, restaurant and ATM, the SWC is located near a residential community. According to CISCO (2008):

> *"The use of SWCs benefits workers by providing a physical workplace close to their residences, resulting in reduced transportation demands and increased productivity. The SWC features a wider 'cloud' of services that not only allows for seamless work experience, but also aims to optimize workers' daily lives."*

A similar initiative for a SWC, "Smart Work@Ijburg", is planned to be implemented at Ijburg. Amsterdam Smart City (2013) intends to bring the SWC "near the homes of the employees that are normally stuck in the traffic jams", given that "every day several kilometers of traffic jams block the entrances and exits to the island which makes Ijburg a very suitable location to get people out of their cars".

In other parts of the city, the "TPEX (Telepresence Exchange International) – Smart Airmiles" initiative (see Figure 20), which involves a network of Telepresence Conference Centers comprising meeting rooms, boardrooms or classrooms, has been implemented. These includes locations such as Amsterdam Bright City, Spaces Zuid-As, WTC Amsterdam, WTC Schiphol, Naritaweg, Amsterdam Arena, Spaces / Herengracht, Beus van Berlage, New Media Hub Almere, etc (Amsterdam Smart City 2013).

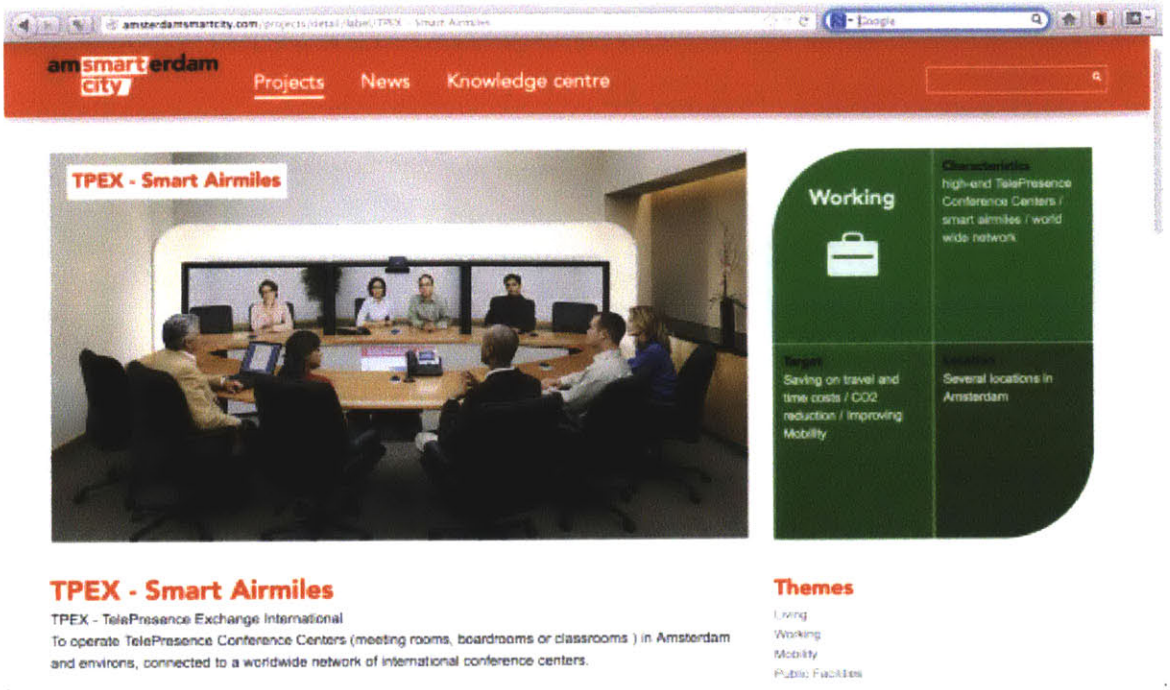

Figure 20 - Amsterdam Smart City: TPEX - Smart Airmiles Initiative
Source: http://amsterdamsmartcity.com/projects/detail/label/TPEX%20-%20Smart%20Airmiles

Mobility

An initiative to support the use of electric vehicles (EVs) and the use of clean, renewable energy is the "ReloadIT" smart grid. Under this scalable initiative, the supply (e.g. PV power) and demand of energy (e.g. schedule of EVs) is matched, with EVs charged to the "maximum daytime loading state of charge" and "surplus of electricity (is) delivered back to the municipality". If the renewable energy predicted for the day is insufficient, the difference in electricity tariffs between day and night is also taken advantage of (E-harbours Electric 2011). Another initiative, the "Moet je Watt Charging System", involves a "smart electrical battery charging system for electric cars that communicates with a smart meter in the meter box to prevent power wastage and overcharging", with the intention to yield cost savings for users (Amsterdam Smart City 2013).

Under the "Ship to grid" initiative, 200 shore power stations were installed in the Port of Amsterdam to allow ships to connect to the city grid (Amsterdam Smart City 2013). This allows the ships to use energy from renewable sources "instead of relying on polluting onboard diesel generators" (see Figure 21).

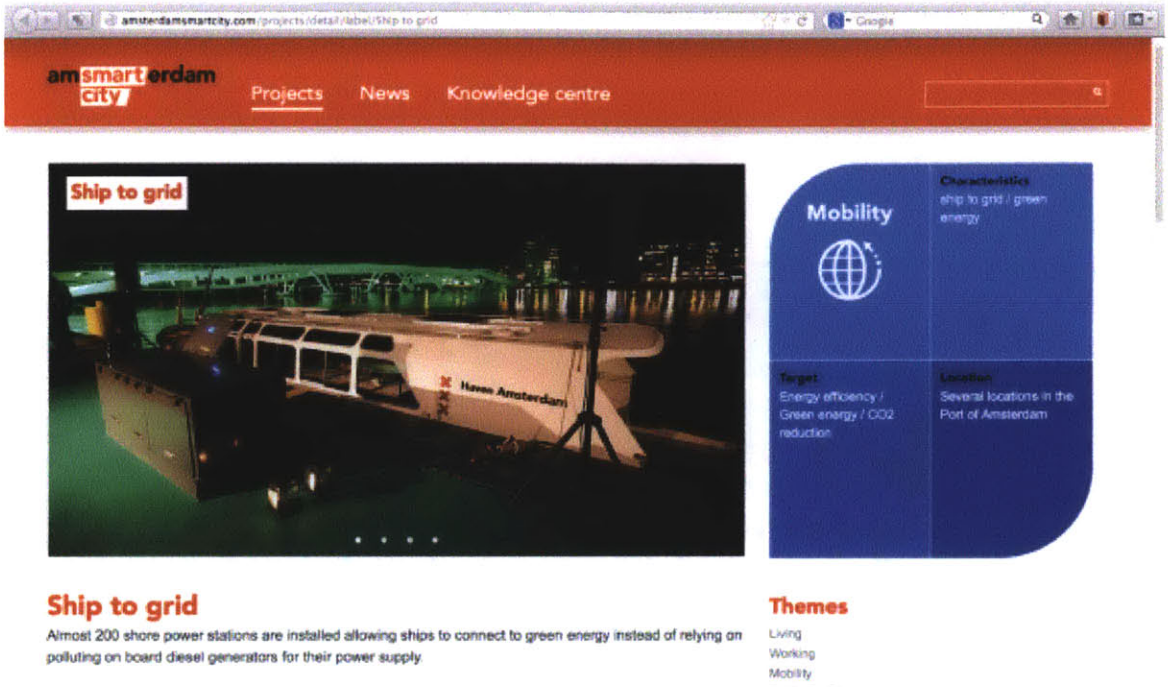

Figure 21 - Amsterdam Smart City: Example of Ship to grid charging station
Source: http://amsterdamsmartcity.com/projects/detail/label/Ship%20to%20grid

"WeGo" is a peer-to-peer car-sharing initiative, which allows users to rent the use of cars from owners by the hour or by the day. This concept allows owners to "make a little more money", provides users with "affordable access to the type of car (they) want", and ultimately "cutting down on the number of cars owned and on the road" (WeGo 2011). The WeGo web portal serves as this car-sharing platform, and provides the insurance and technology for the transactions (see Figure 22).

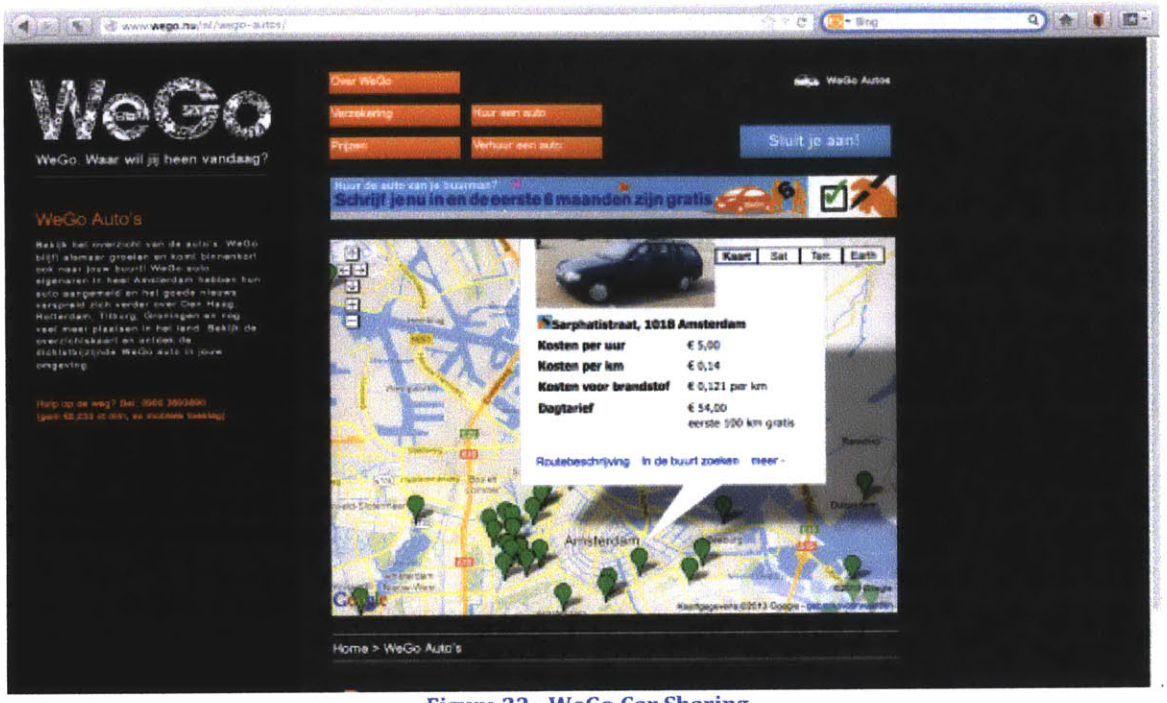

Figure 22 - WeGo Car Sharing
Source: http://www.wego.nu/nl/wego-autos/

Public Facilities

The "Climate Street" initiative along Utrechsestraat, a shopping street comprising shops, cafes and restaurants, is based on a collaborative effort between local entrepreneurs, the city and technology providers. The group mapped out the base measurements of energy consumption and CO2 and NO2 emissions along the street, and subsequently introduced initiatives such as smart meters, energy displays on consumption, smart plugs to automatically dim or shut down appliances, dimmable energy-saving lamps and tram stop lighting, solar-powered BigBelly waste bins, centrally located reverse osmosis water source for cleaning vehicles, clustering and optimization of logistics and deliveries, etc. (Amsterdam Smart City 2013). The street aimed to reduce the overall CO2 emissions from 3,400 tonnes in 2010 to 1,276 tons in 2012, reducing 1,230 tons through energy savings and 894 tons through the use of green energy (Utrechstestraat Klimaatstraat 2011) (see Figure 23).

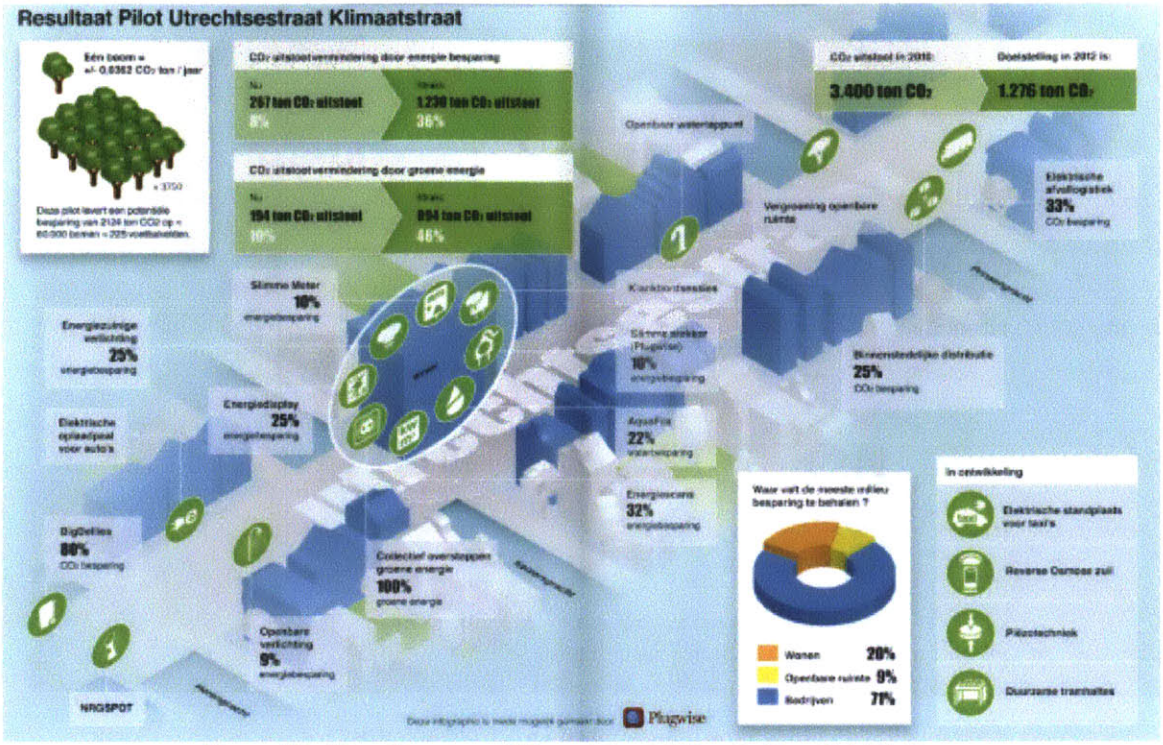

Figure 23 - Utrechtsestraat Klimaatstraat (Climate Street) initiatives
Source: http://issuu.com/klimaatstraat/docs/utrechstestraat_klimaatstraat

Another initiative, the "Smart Schools Contest", involved a competition between 6 elementary schools on energy efficiency. A toolkit for lessons on energy and energy-saving assignments was used for the students, who could also compare their school's score on a web portal (Amsterdam Smart City 2013).

Under the "Zuid Oost – Laws and regulations" initiative, the city is considering the implementation of a "freezone" for the testbedding of sustainability ideas, where rules and regulations are minimized. This arises from the recognition that "technology changes fast, sometimes faster than the context it operates in" and that current regulations such as those regarding solar energy net-metering can "limit the possibilities for home owners to invest in solar panels" (Amsterdam Smart City 2013).

Open Data

The city's "Open Data" portal contains datasets organized in 19 categories, culture and creation, economy, education, urban development, elections, tourism, geography, transport and infrastructure, etc. (see Figure 24). Initiatives such as the "Apps for Amsterdam" competition also encourage app developers to make use of the data in the themes of safety, mobility, vacancy, energy, tourism and culture, and democracy (Amsterdam Smart City 2013).

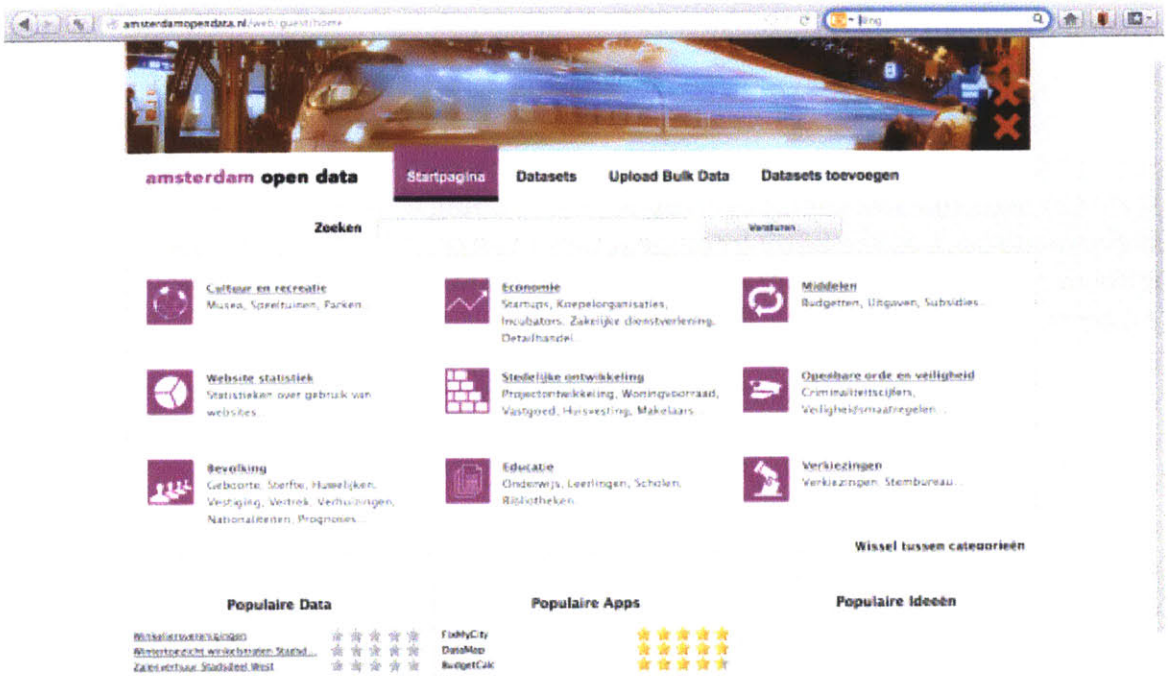

Figure 24 - Amsterdam Open Data
Source: http://amsterdamopendata.nl/web/guest/home

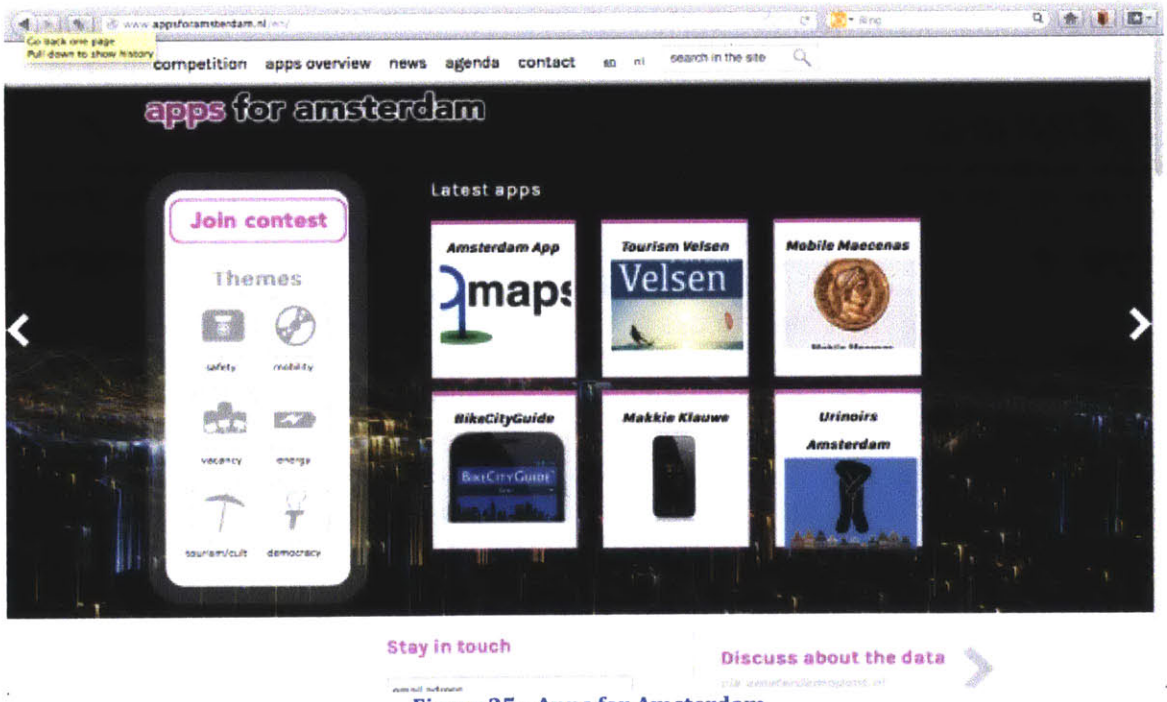

Figure 25 - Apps for Amsterdam
Source: http://www.appsforamsterdam.nl/en/

Stockholm, Sweden

"Smart" city concept

The 2012 Smart Cities Expose report (Smart + Connected Communities Institute 2012b:46) featured Stockholm as a city which "is doing a few things right", given its achievements such as the 2009 Intelligent Community of the Year, 2010 Green Capital of Europe and 4th out of 26th ranking in PricewaterhouseCooper's 2011 Cities of Opportunity study. The city, through its strategic Vision 2030, aims:

> *"...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).*

Stockholm's efforts center on its city-owned company Stokab and its model of providing information infrastructure through a dark fiber network. In this model, Stokab as a public infrastructure company deploys fiber to any potential purchaser on a non-discriminatory basis, but is itself not allowed to sell active services (Felten 2012). The fiber network extended from the city's financial center to the rest of the region and according to Anders Broberg, Chief Information Officer of Stokab, it is "the largest open network in the world with over 125 million km of fiber and 5,500 kn of cable, and with more than 100 operators and 800 companies as customers" (Smart + Connected Communities Institute 2012b:49).

The network thus serves as a backbone IT infrastructure for the city to develop its "smart, green and innovative solutions", as part of the city's vision to be a "connected", "knowledge-rich", "innovative and creative", "sustainable", "inclusive", "service-minded" and "world-class" city (Stokab 2011a). Stockholm's Green IT strategy outlines the city's aims to use IT to reduce its environmental impact, as well as reduce the energy consumption and environmental impact of its IT sector (Holm 2010). This combined environmental-IT approach aims to address issues such as the city's transportation, energy usage, sustainable use of land and water, waste management, reducing GHGe, etc (City of Stockholm 2011). Broberg explains Stockholm's "smart" approach through the Vision 2030 plan, where "it is important to have a holistic view instead of thinking in parts", so that the city can "become this smart city where people want to live and companies want to stay" (Smart + Connected Communities Institute 2012b:49). Some of the city's "smart" efforts will be extended to new sustainable urban development projects such as the Stockholm Royal Seaport.

Examples of "Smart" Initiatives

Vision 2030 & Green IT Strategy: Sustainable Development and IT

An example of an innovative environment-IT initiative is Stokab's installation of one of their fiber network nodes below the Östra Real upper secondary school, to allow the waste heat generated from the telecommunication equipment to heat the school and save money on heating (Felten 2012).

In the future, Stockholm plans to further such "smart" efforts at the Stockholm Royal Seaport, a 236-hectare new development area estimated to be fully completed in 2030, for "innovative environmental technology and creative solutions (to) make Stockholm Royal Seaport a showcase for sustainable urban planning" (Stockholm Royal Seaport 2013). The area, which is one of eighteen global "Climate Positive Development Program" projects, aims to reduce its CO2e per person to 1.5 tons by 2020, and to be "free of fossil fuels" and "climate-neutral" by 2030, and its planning efforts will focus on five areas of "energy use" (e.g. biofuel-fired combined power and heating plant, energy-efficient buildings, smart electricity grids), "environmental efficient transport" (e.g. water transport, public transport, footpaths and cycle tracks), "adaptation to a changed climate", "cycles and cyclical models at system level", and "lifestyle issues".

The area is planned to comprise a "Smart ICT" open and shared communications infrastructure, through requiring developers to connect every individual flat or business with fiber optic cabling. According to Markus Bylund, a project manager:

> *"The project Smart ICT for living and working in Stockholm Royal Seaport is about enabling sectors such as transport, logistics, e-Health, telecommunications and TV to communicate with each other via the same infrastructure. A common communications infrastructure means lower investment costs, less waste of resources, and ... paves the way for the development of new services which can create involvement and participation on sustainability".*

"Smart ICT" will thus "form the basis of an integrated platform" for applications including city management systems and smart street lighting, transport, education and health services (Stockholm Royal Seaport 2013). In terms of energy, Ericsson and Fortum are implementing smart grids "to gather and act on information about the behavior of suppliers and consumers using the grid", in order "to improve the efficiency, reliability and sustainability of electricity production and consumption". For example, individual apartments will be able to retrieve data about energy prices and CO2 impact, for residents to make informed choices. Stockholm, together with Envac, a technology provider focused on waste collection, is planning initiatives such as an automatic vacuum waste disposal system, weighing of waste at the user level, implementing a single food waste chute in the kitchen sink, and energy recovery from the waste collection system.

Figure 26 - Artist's Impression of Stockholm Royal Seaport
Source: http://stockholmroyalseaport.com/

Transportation Management

Recognizing that the transportation sector contributes to 31% of the city's CO2e, 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, Stockholm developed a pilot traffic and congestion management system with IBM. The system included eighteen roadside control points with variable toll rates to influence traffic patterns and congestion levels, in-car transponders that triggered automatic payment, and the use of optical character recognition to identify license plates (IBM 2013a). IBM (2010b) reported that the system had "reduced traffic ... by 20%, reduced average travel times by almost 50%, (and) decreased the amount of emissions by 10%". In addition, Stockholm collaborated with IBM and KTH Royal Institute of Technology to gather real-time information from GPS devices in taxis, analyze traffic conditions, and provide members of the public the fastest routes to their destinations.

The city provides comprehensive transportation information through its website, including public transportation timetables and routes, current traffic speeds on roads and highways (see Figure 27), disruptions in public transport services, road works, traffic accidents, road and weather conditions through traffic cameras (see Figure 28), cycling routes and facilities (see Figure 29), parking facilities, as well as a journey planner. The journey planner allows the user to view route choices between places of origin and destinations, as well as different modal choices. For each modal choice, the length and cost of the journey and the estimated CO2e per

month weighted by vehicle fuel type is also shown (see Figure 30), allow users to plan. The journey planner is also available as a mobile app.

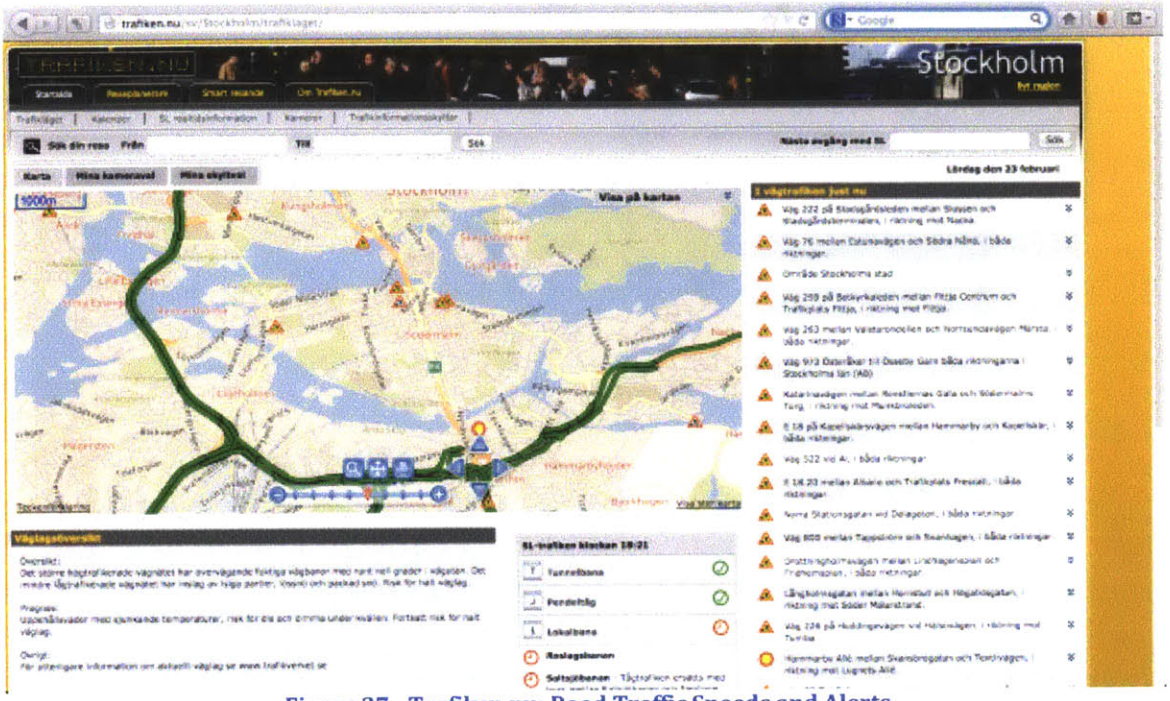

Figure 27 - Trafiken.nu: Road Traffic Speeds and Alerts
Source: http://www.trafiken.nu/sv/Stockholm/trafiklaget/

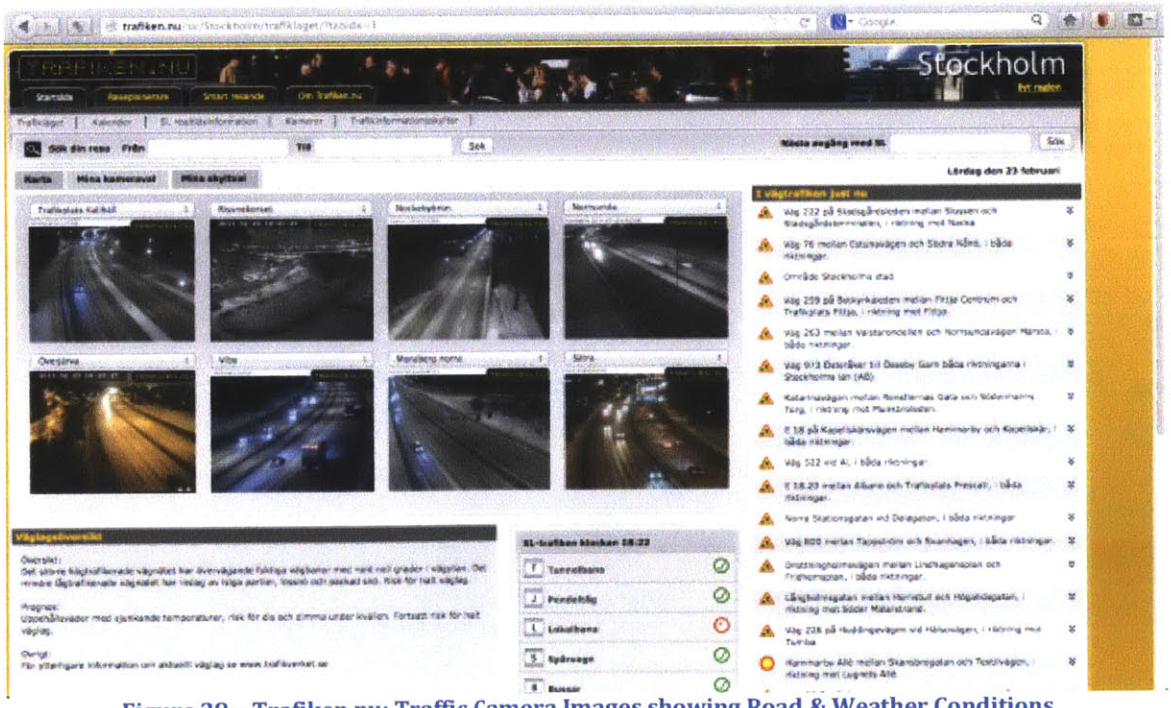

Figure 28 – Trafiken.nu: Traffic Camera Images showing Road & Weather Conditions
Source: http://www.trafiken.nu/sv/Stockholm/trafiklaget/?tabidx=1

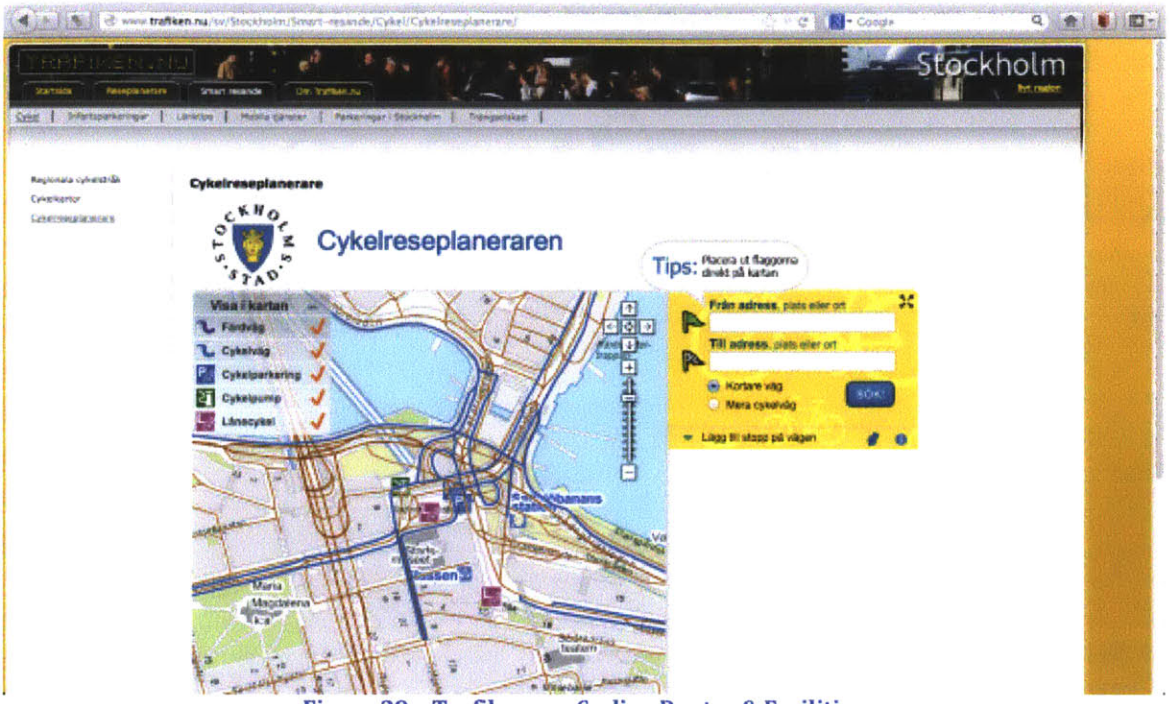

Figure 29 – Trafiken.nu: Cycling Routes & Facilities
Source: http://www.trafiken.nu/sv/Stockholm/Smart-resande/Cykel/Cykelreseplanerare/

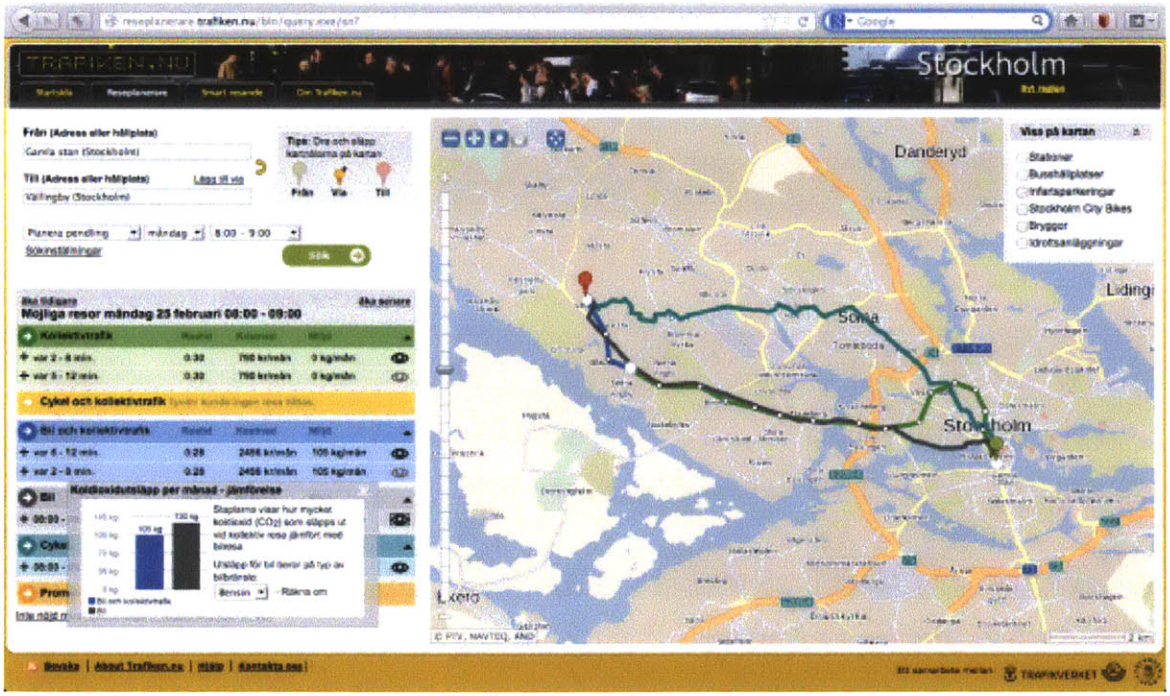

Figure 30 - Trafiken.nu: Journey Planner
Source: http://reseplanerare.trafiken.nu/bin/query.exe/sn?

Citizen Services and Internet Access

The City has a comprehensive range of e-services grouped in various categories – e.g. "Family", "Leisure", "Caring for Persons with Disabilities", "Preschool", "School", "Household", "Sports / Exercise", "Childcare", "Support for the elderly", "Culture", etc. Figure 31) – to provide better citizen services, "work smarter" and "more efficiently in order to free up resources" and to be more transparent (Stockholm City Council 2010). According to Stokab (2011a), the e-services are well-used, for example, "90% of parents apply for places at day-care centres for their children online, the city's heat-pump permit e-service is used by 70% of all applicants, 90% of people booking their marriage service at City Hall do so electronically, and over 70% of students enrolled at schools online".

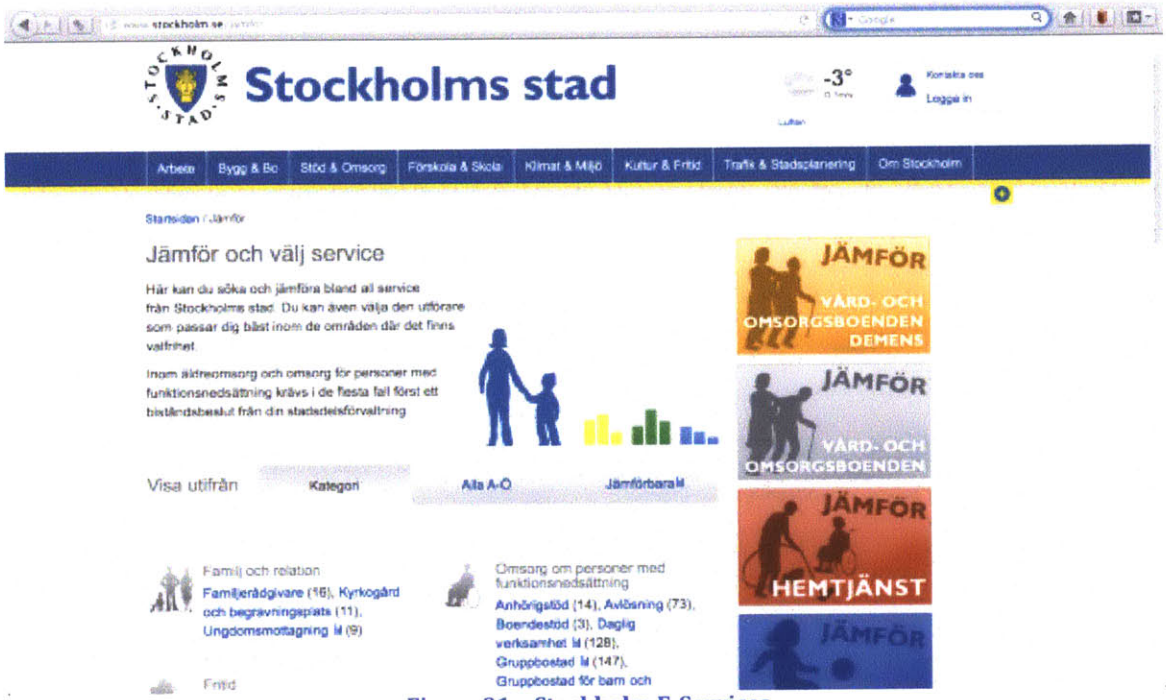

Figure 31 – Stockholm E-Services
Source: http://www.stockholm.se/jamfor

In another initiative, the city equipped homecare workers and providers with a smart phone to document their daily operations on more than 30,000 elderly citizens (Healthcare IT News 2012). This system, which is more efficient and improves the quality of documentation, also allows relatives to access the documentation from remote locations.

The city also ensures a high level of public internet connectivity. Together with S:t Erik Kommunikation and Cisco, the city upgraded its schools' broadband access to include wireless network facilities (Cisco 2011). Low-income households were provided with high-speed internet connections and assistance and training is given to the homeless (Stokab 2011a).

Open Data

In 2011, Stockholm launched its "Open Data" portal and began to release APIs for access to its data. The intention was to encourage "private entrepreneurs (to) come up with business ideas with the help of the city's rich information resources" and for residents to "see new and currently unknown opportunities by getting access to the information" (Stockholm News 2011). The city also launched the "Open Stockholm Award" for "the development of smart apps and web services", with prizes for the best idea, most innovative app, best app for sustainability and the environment and smartest solution for Stockholmers (City of Stockholm 2012b). The "Open Data" and geodata portal (see Figure 32) includes datasets on population, city activities and satisfaction survey results, geodata, environmental data, and traffic and parking data.

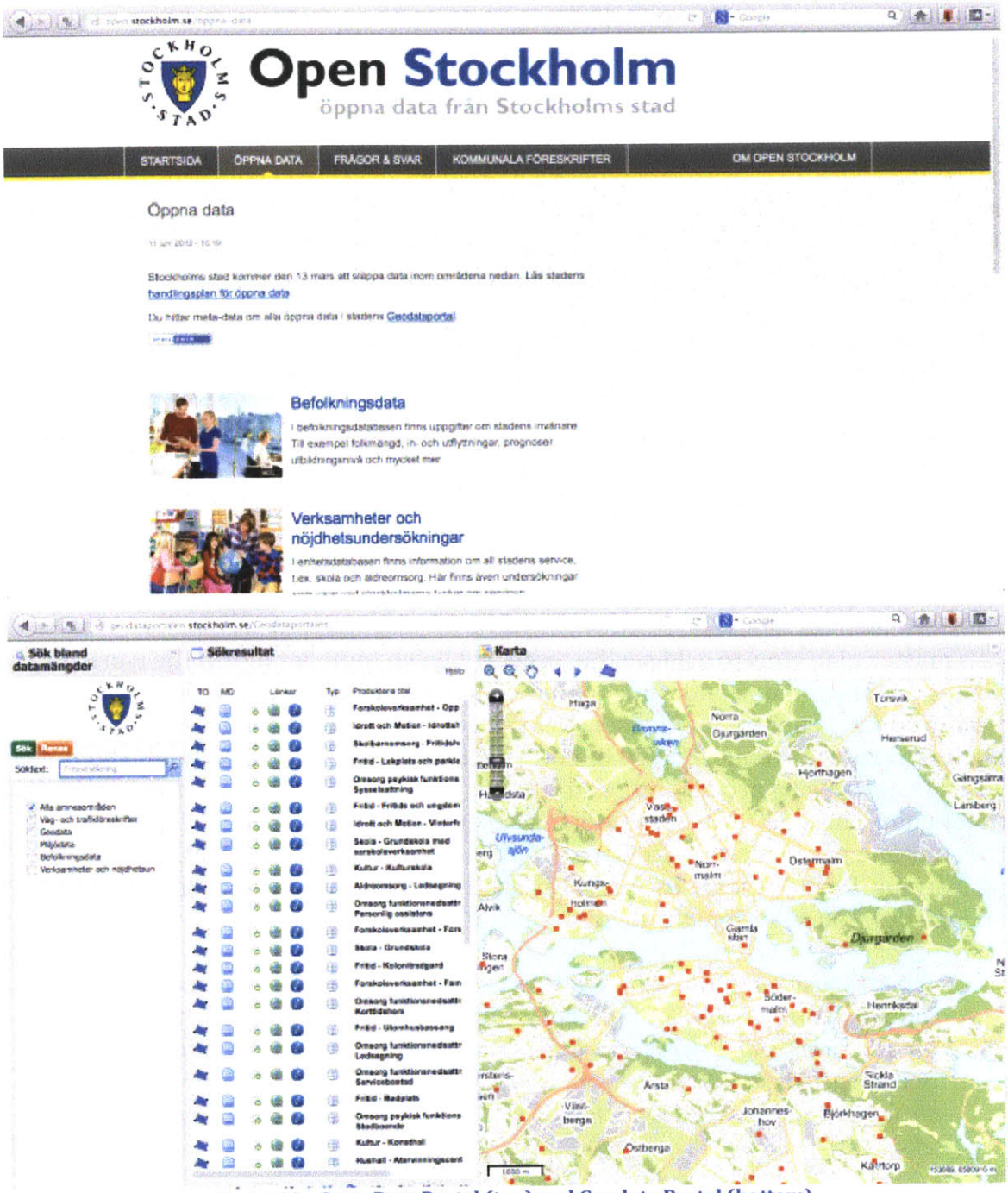

Figure 32 - Open Data Portal (top) and Geodata Portal (bottom)
Source: http://open.stockholm.se/oppna-data

Singapore

"Smart" city concept

Singapore's "smart" efforts center on the application of ICTs to "revolutionize the way people work, live, learn and interact" (Smart + Connected Communities Institute 2012b:39). These efforts stem primarily from its Intelligent Nation 2015 (iN2015) master plan, led by the Infocomm Development Authority (IDA). The iN2015 master plan focuses on harnessing ICTs to meet the city's three objectives of innovation, integration "within organizations and businesses, and between individuals, sectors, communities and geographies", and internationalization, where ICTs facilitate Singapore's "access to the world's resources" and "export... of... ideas, products, services, companies and talent" (IDA 2006a:7). According to Tay (2013a), the "smart" efforts involve the use of ICTs as "enabling infrastructure" whereby "different domains are brought together under a systems approach" and where data is gathered, used and analyzed for decision-making; these lay the foundations for "experimentation and risk-taking to enable the development and piloting of new concepts" and "to address complex challenges... through practical and efficient solutions" (Tay 2013b).

IDA's master plan aims to achieve the targets of being "number one in the world in harnessing infocomm to add value to the economy and society", a "two-fold increase in value-added of infocomm industry to S$26 billion", a "three-fold 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 master plan also outlines strategies for seven key economic and government sectors, i.e. digital media and entertainment, education and learning, financial services, healthcare and biomedical sciences, manufacturing and logistics, and government. Its four main thrusts are:

> *"To establish an ultra-high speed, pervasive, intelligent and trusted infocomm infrastructure; to develop a globally competitive infocomm industry; to develop an infocomm-savvy workforce and globally competitive infocomm manpower; and to spearhead the transformation of key economic sectors, government and society through more sophisticated and innovative use of infocomm."* (IDA 2006a:8)

Hence, the iN2015 master plan reflects Singapore's emphasis on the application of ICTs in its economy, society and government.

The Economic Development Board (EDB), which is the "lead government agency for planning and executing strategies to enhance Singapore's position as a global business center" (EDB 2012), has identified "urban solutions" as an economic sector to pursue. This includes the sub-sectors of environment and water, clean energy, built environment and city management, urban mobility, IT and infocomm, public safety. Through these sub-sectors, EDB aims to develop Singapore as a 'living lab'

for industry partners to "test new concepts, develop and commercialize cutting-edge 'urban solutions', capitalizing on Singapore's experience" (EDB 2010). EDB's approach is thus dual; "smart" initiatives that serve Singapore's needs are also marketable as economic "urban solutions".

Singapore's vision for government is "to be an integrated government that delights customers and connects citizens through infocomm" (IDA 2006b:16). This is based on four strategic thrusts of "increasing reach and richness of e-services", "increasing citizens' mindshare in e-engagement", "enhancing capacity and synergy in government", and "enhancing national competitive advantage".

Examples of "Smart" Initiatives

Citizen Services, Data and Data Analytics

Singapore's "e-Citizen" services web portal is a one-stop shop for citizens, businesses and non-citizens, as well as access to all government-related communication and information.

In terms of citizen services, users can access 385 of the most common e-services from 60 ministries and statutory boards (e-Citizen 2013), out of a total of 1,600 e-services (IDA 2006b:16) available online. These services serve a diversity of citizen needs. For example, users are able to file their income and property taxes online, pay their housing mortgage loans, access the database of schools, pay their parking fines, apply for their passports, make medical appointments in any public health center, apply for exit permits for military national servicemen, make online enquiries on government child incentives, etc (see Figure 33). Many of these services can be accessed via "SingPass", a single common password for government e-services based on the national registration identification number (Government of Singapore 2013a).

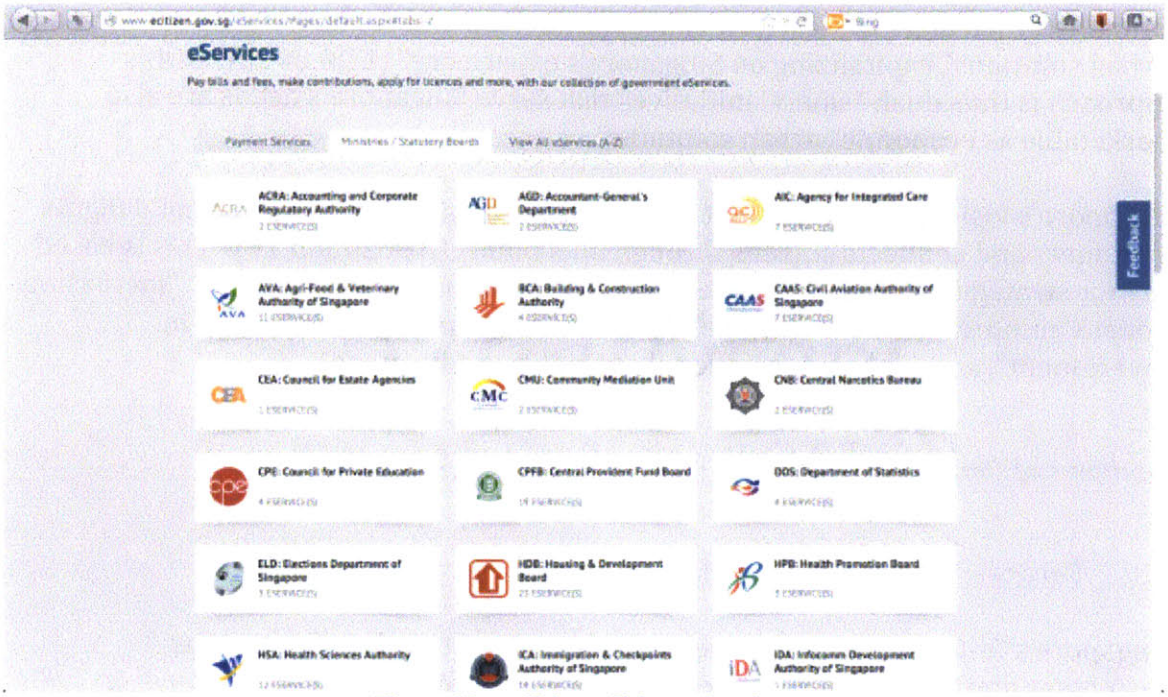

Figure 33 - e-Citizen: Citizen eServices
Source: http://www.ecitizen.gov.sg/eServices/Pages/default.aspx#tabs-2

To cater to businesses, the "EnterpriseOne" portal employs a slightly different format, with information topics that include on local laws and regulations, taxes, procedures for setting up businesses, overview on various economic and industrial sectors, avenues for government assistance, etc. Links to various relevant e-services are included, for example, for registering new businesses and apply for licenses and permits. For non-citizens, another portal comprises mainly information topics such as customs, citizenship application, employment and student pass, taxation, healthcare services, tourist information, etc.

The "Reach" e-engagement web portal, together with its other media channels (e.g. email, Facebook, Twitter, etc.), aims to "encourage and promote public participation in shaping government policies" (Reach 2013). This portal serves as a one-stop shop for citizens to access all public consultations on proposals and policies, proposed amendments to legislations, etc. from all government agencies, and take part in online polls and discussions.

In terms of data, the "Data.gov.sg" portal allows users to search and access data from over 5,000 datasets from 50 government agencies (Government of Singapore 2013b). The data include textual and tabular statistics and indicators pertaining to each agency's function, as well as links to raw geo-located data. These geo-located data (e.g. street map, cadastral plan, regulatory land use Master Plan, location of community and social facilities, government offices, etc.) can also be viewed via "OneMap". In addition, users can access a number of services. For example, users can access data on all property transactions by location, property type, transaction period, price range, etc (see Figure 34). Related to policies on admission to primary

schools, users are also able to visualize residential address locations within 1km to each school (see Figure 35). Other services include searching for business addresses, rental of government-owned property and space, as well as links to other mapping services such as bird-watching hotspots, community volunteer opportunities, family and childcare services, etc.

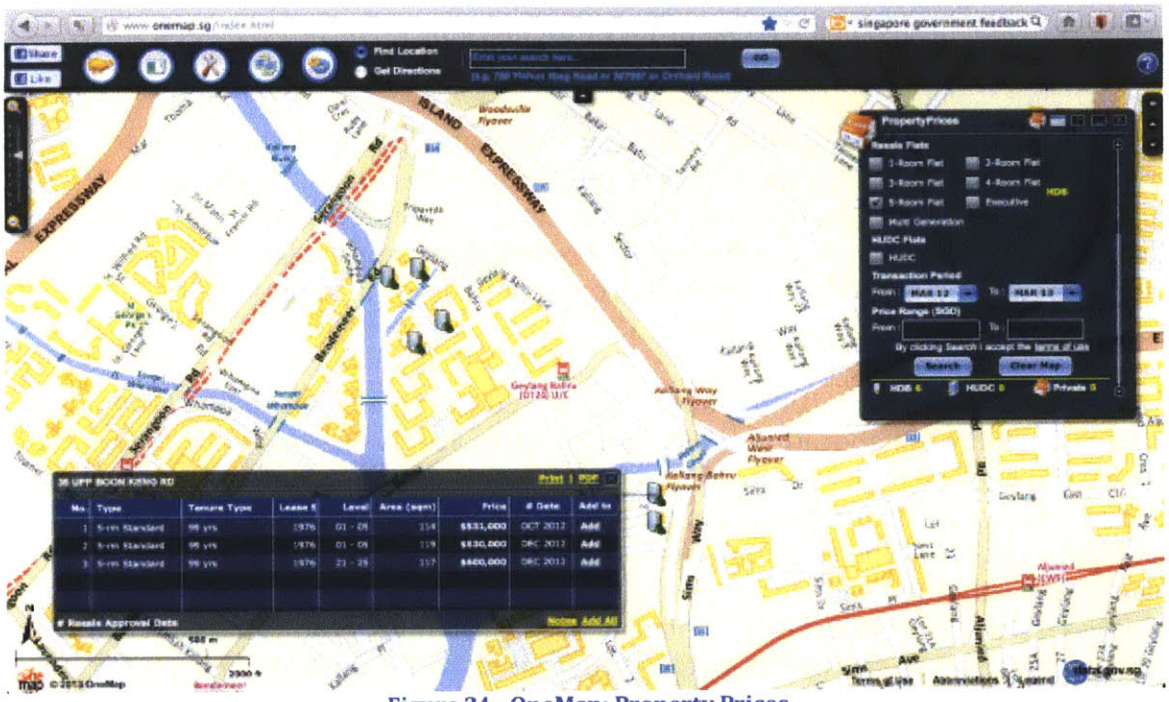

Figure 34 - OneMap: Property Prices
Source: http://www.onemap.sg/index.html

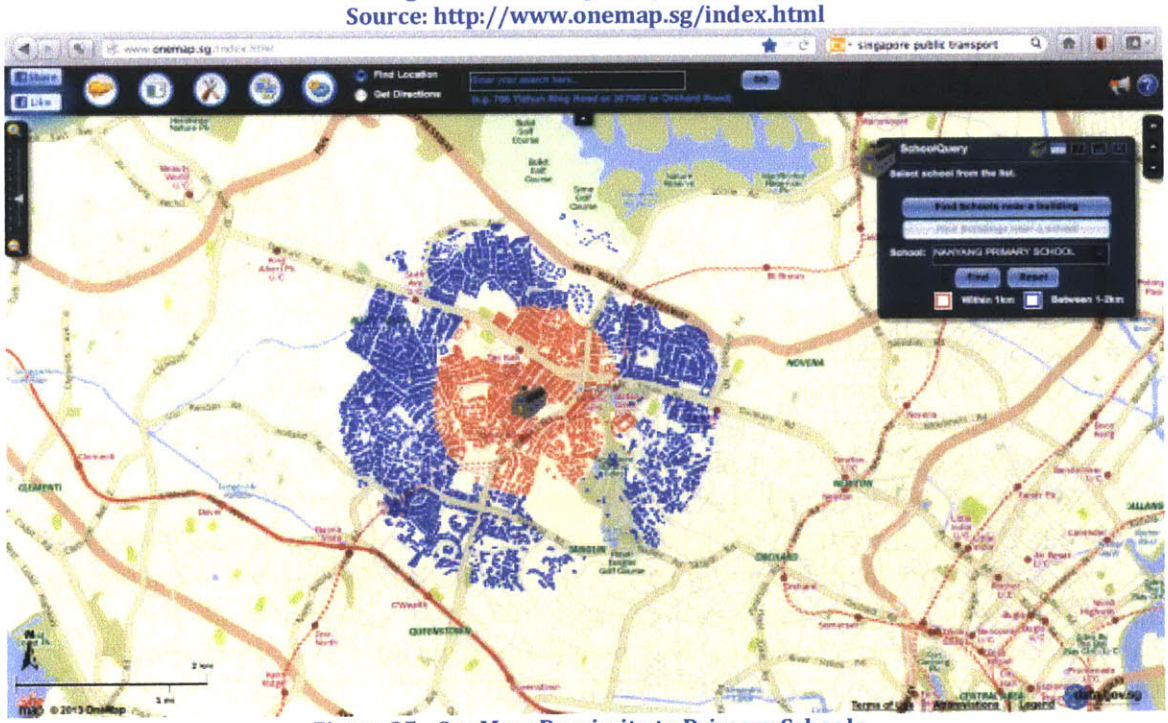

Figure 35 - OneMap: Proximity to Primary Schools
Source: http://www.onemap.sg/index.html

A number of mobile apps have also been developed by government agencies, as well as in collaboration with the private sector (Government of Singapore 2013b). For example, the "Police@SG" app provides crime statistics in different neighborhoods and latest crime news and police appeals. "Waalkz" is an interactive self-guided walking tour app through Singapore's historic districts that uses data from the National Heritage Board. The "ShowNearby" app allows users to search for locations of amenities such as restaurants, atm machines, clinics, etc., using data from government and other sources.

In addition, agencies like IDA and EDB support private hackathon initiatives to source for new ideas and apps. For example, through the "UP Singapore" collaborative platform, energy and environment themed ideas including a portal allowing users to trade pre-loved toys, an air-conditioning use management system, a social media app based on a user's environmental footprint, a car parking lot reservation app, etc (Newton Circus 2013).

In terms of data analytics, IDA is supporting the efforts of local technology providers through Calls-for-Collaboration (CFC). For example, IDA is working with consortia partners to explore the implementation of new location-based analytical services such as indoor navigation combined with targeted marketing, as well as the establishment of an Open Positioning Framework (Tay 2013b). Another CFC focuses on facilitating and encouraging the adoption of social analytics by local businesses, for example through enhanced "social listening" (gathering data from social media), "cross-channel analytics" (integrating social media and consumer touchpoints) and "social engagement" (IDA 2013b). IDA's "Business Analytics Innovation Challenge" is another platform for technology providers to develop innovative data analytics products in collaboration with research institutions, data scientists (IDA 2013c).

Infocomm Infrastructure and Access

In terms of infocomm infrastructure, Singapore's "Next Generation Nationwide Broadband Network" is a major initiative that aims to connect 60% of households to a high speed 1Gbps fiber broadband network; as at December 2012, a survey showed that 1 in 5 households had subscribed to the network (OpenNet 2012). IDA's "Wireless @SG" initiative provides free wi-fi in public areas islandwide with access speeds of 1 Mbps. IDA is also working with the industry on the expansion of the 4G mobile network and release of more spectrum, as well as new initiatives such as Near Field Communication (NFC) electronic payment infrastructure (Tay 2013a). Other IDA initiatives include setting up a "Grid Market Hub" where local businesses can access grid computing services on a pay-per-use model, a "National Authentication Framework (NAF)" that provides strong authentication services for businesses and consumers, et.c (IDA 2012).

Within the public education system, some schools under the "FutureSchools@Singapore" program test new ICT-enabled learning ideas. For example, Canberra Primary School students use immersive gaming and multi-user virtual learning environments and smart devices on interactive field trips. Crescent Girl's School uses its "i-Connect Learning Space" platform that includes teaching courseware and digital textbooks, as well as a "Virtual Global Learning Faculty" web-portal with collaborative tools and resources for teachers and students (Ministry of Education 2010).

To encourage access to ICTs especially for children from low-income households and the elderly, IDA has a number of initiatives (IDA 2006b). These include a subsidized program for low-income households to own a new personal computer and a three-year free broadband subscription, training and subsidized computer equipment for senior citizens, and training for people with disabilities.

Transportation

In terms of transportation, Singapore's Land Transport Authority (LTA) has embarked on a number of initiatives. For example, it implemented the "e-Symphony" fare card system in collaboration with IBM, which provides a single stored value card for payments for public transportation, private vehicle congestion charges and parking, increasing convenience and lowering costs (IBM 2009). Also in collaboration with IBM, the LTA developed a "Bus Arrival Prediction" tool to "help enable the delivery of more accurate bus arrival times for commuters" (IBM 2010c), and a "Traffic Prediction Tool" to "anticipate and better manage the flow of traffic to prevent the build-up of congestion" (IBM 2007).

To inform users and facilitate their decisions on transportation options, LTA has implemented a number of web and mobile apps. For example, LTA's "Traffic.Smart" website provides information on real-time traffic speed along roads, information on incidents such as road works and accidents, traffic camera images, as well as charges for each specific Electronic Road Pricing (ERP) gantry (see Figure 36). The "PublicTransport@SG" web portal provides comprehensive information on bus and rail schedules, arrival times, fares, as well as an interactive map with locations and information on bus stops and rail transit stations.

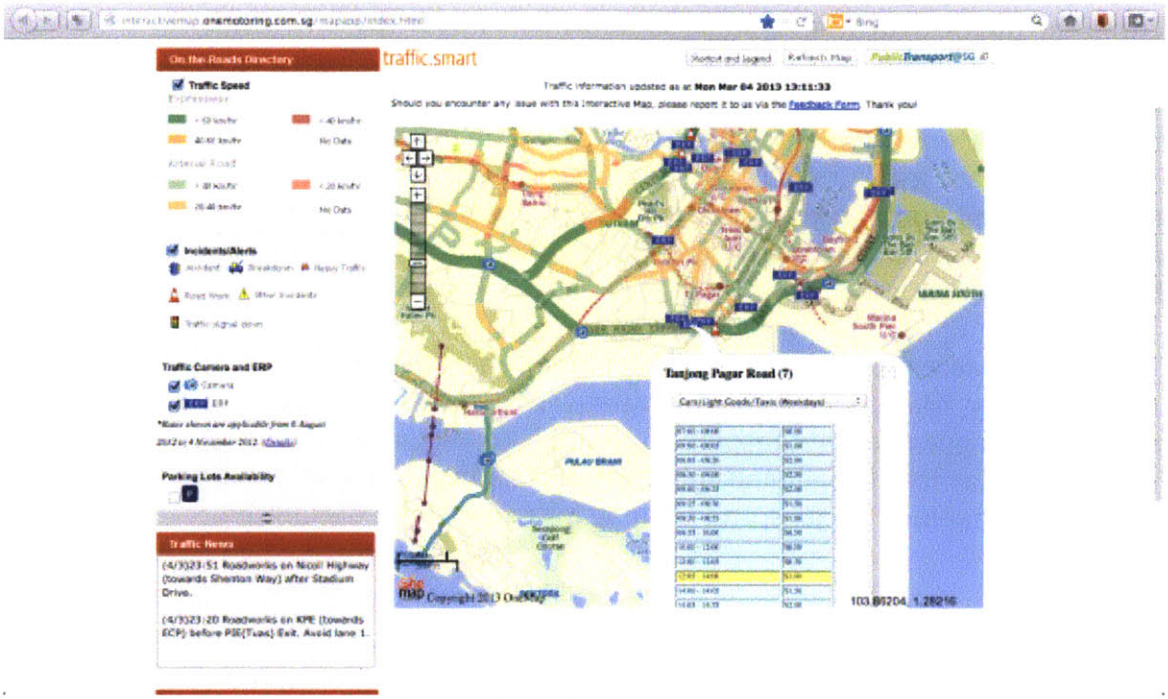

Figure 36 - Traffic.Smart web app
Source: http://interactivemap.onemotoring.com.sg/mapapp/index.html

The information on motoring and public transportation are also made available through LTA's mobile app, "TransportSG". For example, as shown in Figure 37, users are able to access information such as bus stop and bus arrival times, number of available parking lots in real-time, cycling routes, etc.

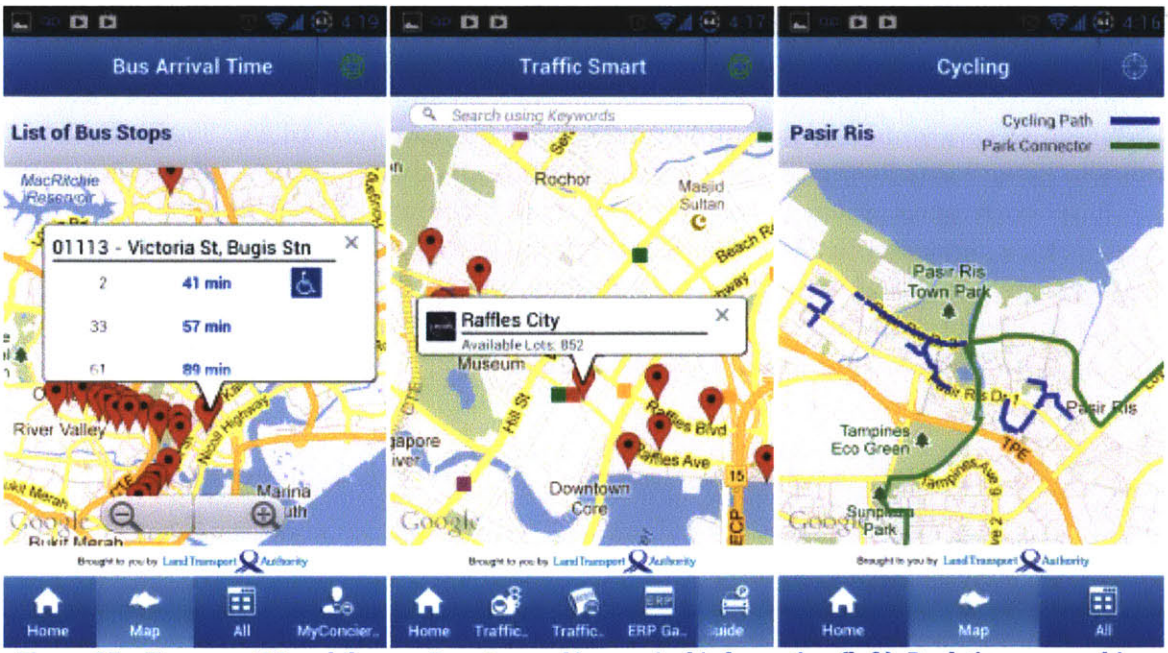

Figure 37 – TransportSG mobile app: Bus stop and bus arrival information (left), Real-time car parking information (center), Cycling routes (right)
Source: https://play.google.com/store/apps/details?id=sg.gov.lta.mytransport

Environmental Monitoring, Integrated Sustainable Development and Urban Solutions

Singapore's "smart" initiatives in the field area of environmental monitoring include the "MyENV" app published by Singapore's National Environment Agency (NEA) which provides users access to a number of real-time environmental data. This includes, for example, information on the water level of stormwater drains throughout the island that helps in the assessment of flash flooding, air quality conditions, as well as occurrences of dengue fever by address points and identified clusters (see Figure 38).

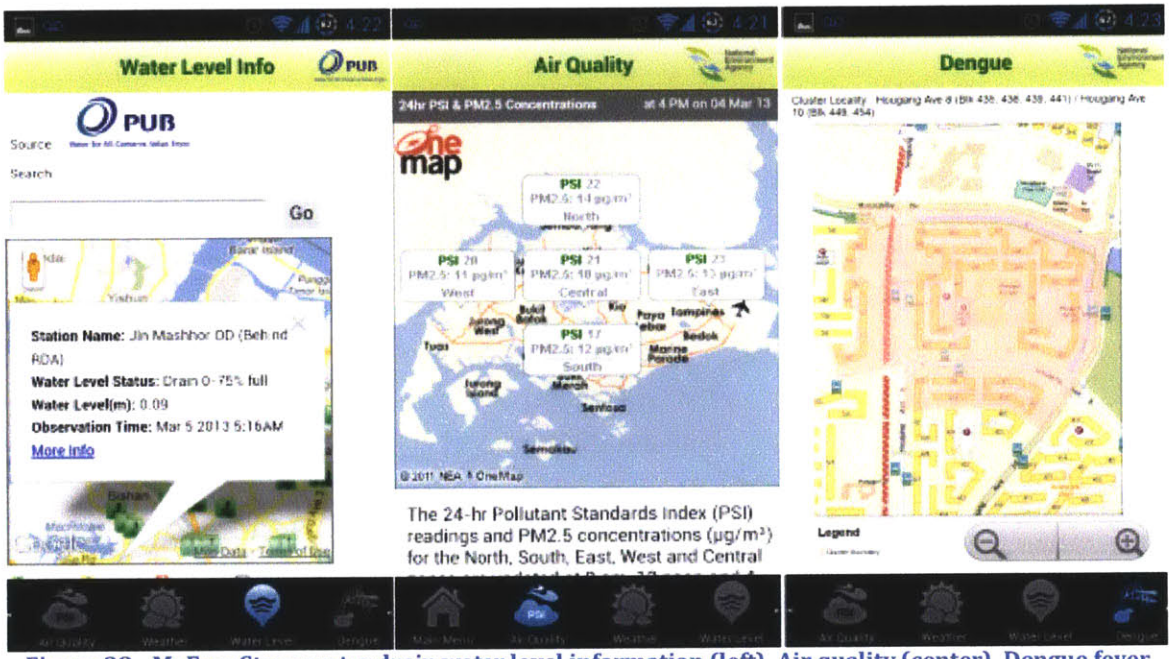

Figure 38 - MyEnv: Stormwater drain water level information (left), Air quality (center), Dengue fever occurrence clusters (right)
Source: https://play.google.com/store/apps/details?id=sg.gov.nea&hl=en

Apart from environmental monitoring, other apps play a role in raising awareness and educating users (Government of Singapore 2013b). For example, NEA's "Energy Audit" app provides users with an estimated breakdown of energy consumption by household appliances, identifying high "energy guzzling" appliances. "EcoFinder@SG" is an interactive app which encourages users to recycle through a social media element and provides information on recycle bin locations. The "Life Cycle Cost Calcuator" helps users calculate and compare the estimated total consumption cost over the life cycle of different household appliances.

The "Intelligent Energy System (IES)" initiative is a collaborative pilot project by the Energy Market Authority (EMA) and Singapore Power, an energy provider, which "seeks to test and evaluate new applications and technologies around a smart grid" (EMA 2010). For example, under the initial phases, households are equipped with a

"Smart Meter" that allows users to view details of their electricity consumption through a web portal, home display unit, mobile devices and notifications. The intention is to further develop applications on top of such "advanced metering infrastructure" in future phases. For example, these include time-of-use tariff information, demand response and energy management, outage management, and integration of electric vehicle (EV) charging and vehicle-to-grid functions (EMA 2011).

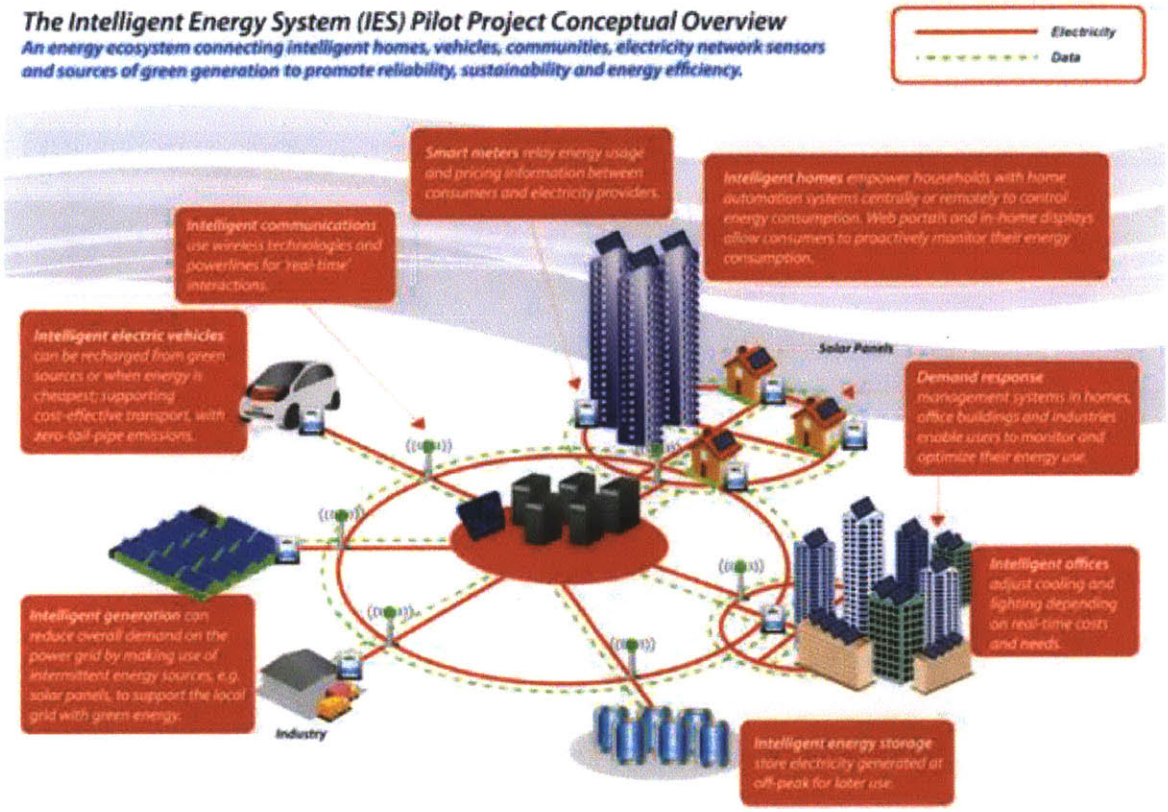

Figure 39 – Intelligent Energy System (IES) Pilot Project Conceptual Overview
Source: http://www.ema.gov.sg/ies

In 2012, Singapore's Jurong Lake District was named as one of IBM's Smarter Cities Challenge Grant recipients. This collaborative effort, between IBM, Singapore's Urban Redevelopment Authority (URA), the planning authority, EDB and partner agencies including IDA, aims to "explore innovative solutions to enhance Jurong Lake District as a smart, sustainable, and connected high-density district" (URA 2012). In parallel, the city agencies are launching a Call-for-Collaboration with technology providers to "collaborate and conduct pilots and trials of smart technologies in JLD" (IDA 2013d). For example, according to a city official from EDB (2013), these could involve central dashboard for transportation and energy management. IDA will also deploy connectivity-enhancing infrastructure and sensors to "enable access to real-time data and pervasive ICT connectivity" (Tay 2013b). These support the planning vision for Jurong Lake District to "use

resources more efficiently, optimise land, and enhance the quality of life for its workers, residents and visitors" (URA 2012), as well as "bring about more efficient operations and informed planning for government agencies and user organizations" (Tay 2013b). The EDB official highlighted that the process involved identifying problem statements by various agencies, which would then be opened to the private sector / technology providers for solution-seeking, as well as allowing room for technology providers to propose their own "test cases" in line with the district's planning objectives (IDA 2013d).

An example of a similar idea for a centrally managed system is Siemens' "City Cockpit" implemented in Siemens' office in Singapore. The "cockpit" is envisaged to use ICTs to support decision-making, whereby "important information flows into a central system that processes the data for convenient display and indicates to what extent specified objectives are being met" (Bartsch 2011). For example, this could include traffic management, as well as the management systems of the energy network, water supply system, public finances, etc.

Rio de Janeiro, Brazil

"Smart" city concept

Rio de Janeiro's "smart" program is synonymous with its Rio Operations Center Operations (Centro de Operações Rio, COR). Developed in partnership with IBM, COR opened in 2010 and integrates and coordinates the functions of over 30 city agencies and private transportation and utility companies, including emergency management, prediction and response management to events such as heavy rains, landslides and traffic incidents (Municipality of Rio de Janeiro 2013).

According to Mayor Eduardo Paes, the function of COR and the application of ICTs are instruments that "benefit the population and effectively transition(ing) to a smarter city", allowing quick and reliable communication with the city's citizens, "so as to empower them with initiatives that can contribute to an improved flow of city operations" (Sterling 2011). Mr Carlos Osorio, the Secretary for Conservation and Public Services, highlights that the city's "smart" model involving COR provides a "collaborative tool for city workers, city officials and external agencies and companies", where COR serves as a "catalyst to make the broader metropolitan area function better" (Smart + Connected Communities Institute 2012b:24). Hamm (2012) describes COR as the "first such facility in the world" and that:

> *"... it embodies the principle that only by considering and coordinating the human-made and natural systems of a city in a holistic way can municipal leaders hope to manage the complexities of a large, modern city."*

COR is hence likened to be a "nerve center" (Sterling 2011), where IBM's analytical models assess real-time and historical data to predict and coordinate the city's emergency response.

Examples of "Smart" Initiatives

Transportation and Events Management

COR receives a live stream of images from 560 traffic cameras and monitors traffic conditions, allowing it to divert traffic, for example, in the event of incidents. The real-time data also helps the city manage crowd-intensive events (Heim 2011), for example, the Carnival or New Year's Eve, as well as the upcoming 2014 FIFA World Cup and 2016 Summer Olympic Games. COR also integrates a Situation Room, where city leaders and emergency response officials can communicate and make decisions.

Figure 40 - Centro de Operações
Source: http://ipprio.rio.rj.gov.br/centro-de-operacoes-rio-usa-mapas-feitos-pelo-ipp/

Weather Prediction, Emergency Management and Response

In 2010, heavy floods and mudslides caused 200 deaths and made 15,000 homeless (Heim 2011) within the State of Rio de Janeiro, in particular, in the city's hillside favelas. With COR, the city is able to forecast the weather 48 hours ahead including

wind speeds and the intensity of rainfall and runoffs, predict the impacts of possible floods and landslides, coordinate and activate its emergency response agencies and deploy relevant resources. For example, this includes preparing emergency vehicles with fuel, stocking supplies for emergency shelters, as well as identifying facilities like hospitals near affected areas, including information on medical specialties and bed availability (IBM 2013b). COR is also able to warn its citizens through its system of sirens, mobile SMS and email alerts about the impending floods or other emergencies.

Such prediction is made through IBM's "Deep Thunder" high-resolution weather forecasting and hydrological modeling system (see Figure 41) "based on a unified mathematical model of Rio that pulls data from the river basin, topographic surveys, the municipality's historical rainfall logs, and radar feeds" (IBM 2011d), which also includes a network of 33 rain gauges for model validation and calibration.

Figure 41 - IBM Deep Thunder Weather Prediction
Source: http://asmarterplanet.com/blog/2010/12/ibm-helps-rio-de-janeiro-become-a-smarter-city.html

Citizen Communication

The city also communicates its information to its citizens via other channels. For example, the COR web portal lists weather, traffic, city alert level and other alerts (see Figure 42) and COR posts key videos on its YouTube channel (see Figure 43).

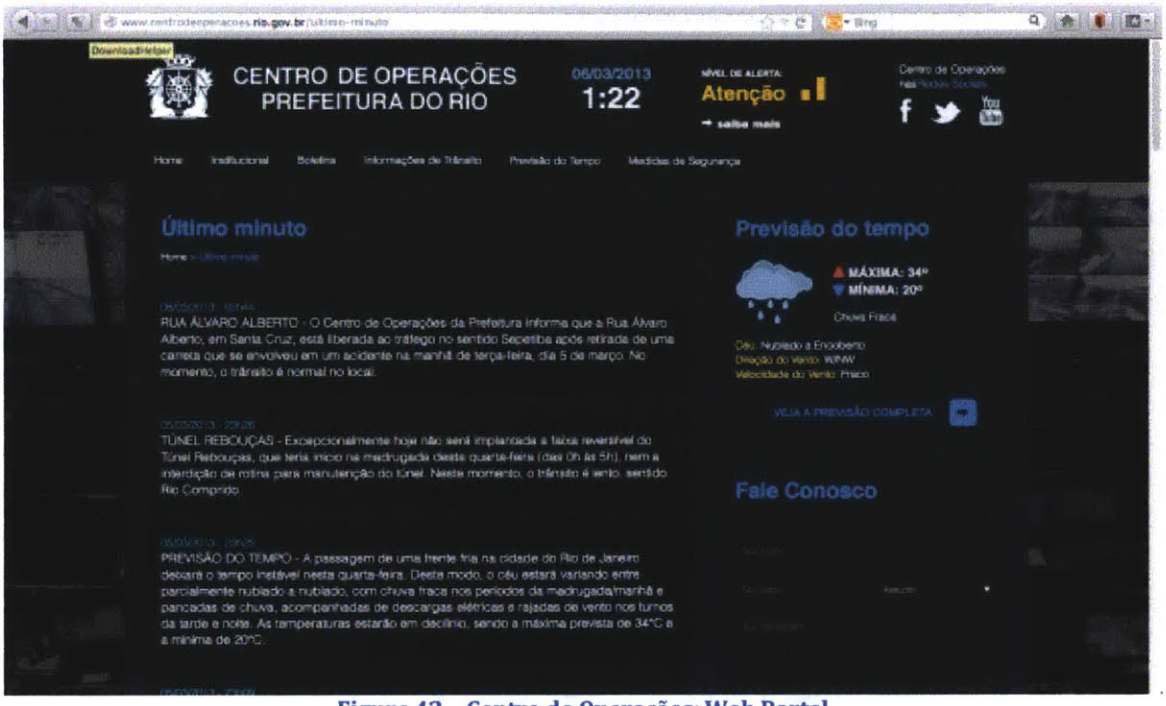

Figure 42 – Centro de Operações: Web Portal
Source: http://www.centrodeoperacoes.rio.gov.br/ultimo-minuto

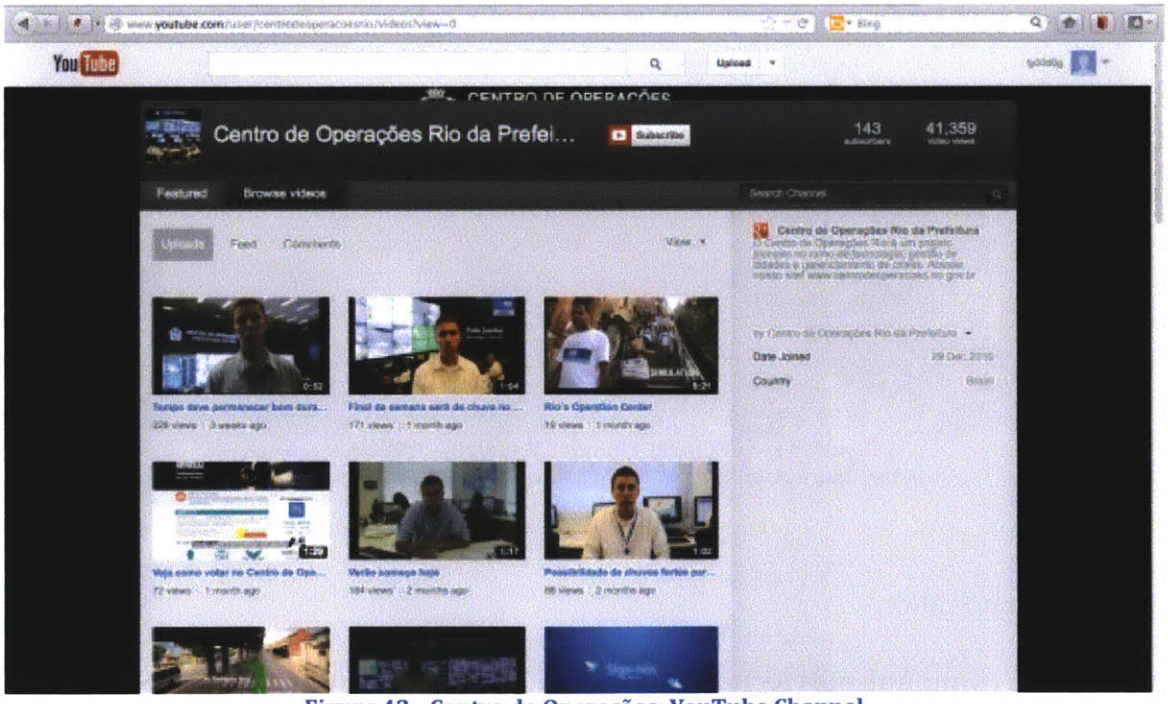

Figure 43 - Centro de Operações: YouTube Channel
Source: http://www.youtube.com/user/centrodeoperacoesrio

Its Twitter account also sends regular alerts and updates on traffic information, updates on city administration matters, links to the city bulletin, etc (see Figure 44). Hash tags are also used for various zones within the city, such as "#centro",

"#zonalsul", "#zonaoeste", etc. Similarly, the information is disseminated through its Facebook account (see Figure 45 and Figure 46).

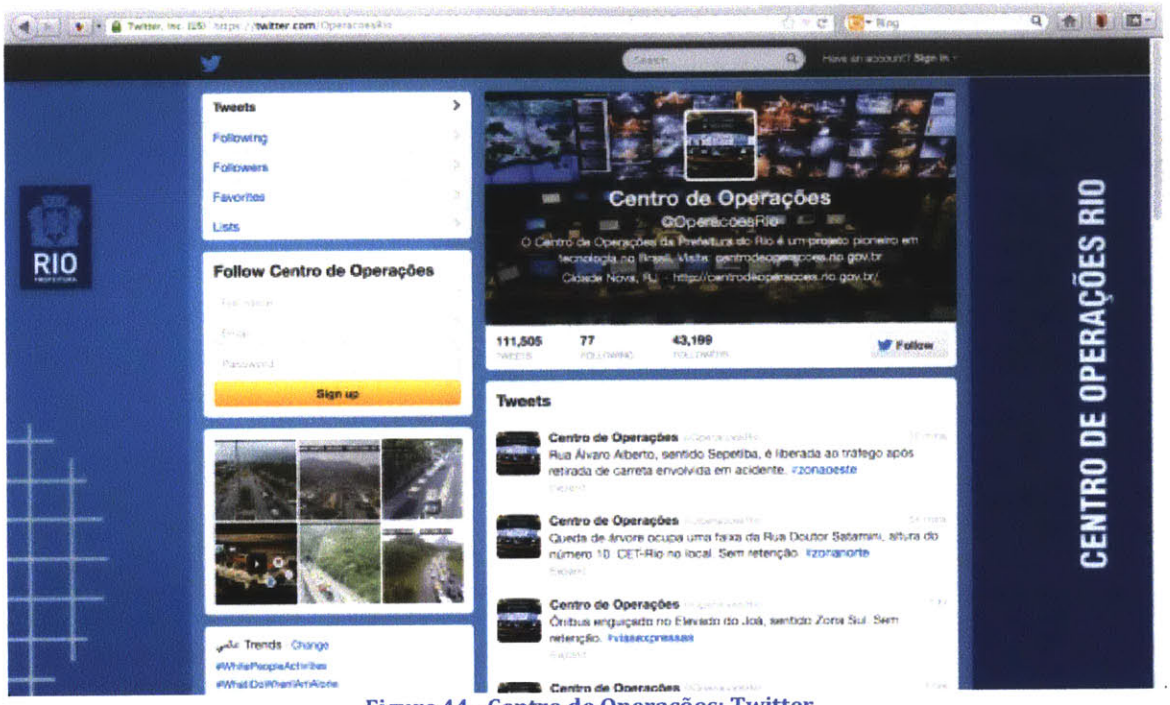

Figure 44 - Centro de Operações: Twitter
Source: https://twitter.com/operacoesrio

Figure 45 – Centro de Operações: Mobile Facebook Profile (left), Traffic Alert (center), Weather Alert (right)
Source: https://www.facebook.com/operacoesrio

Figure 46 – Centro de Operações: Web Facebook Traffic Alert
Source: https://www.facebook.com/operacoesrio

In addition, the city uses its "1746 Rio" app to gather feedback from its citizens. For example, users are able to report faulty traffic signals, public street lighting, potholes, incidents of dengue fever, etc., with textual descriptions, photographs and locations. The app also provides alerts from the city, such as traffic and weather alerts, etc.

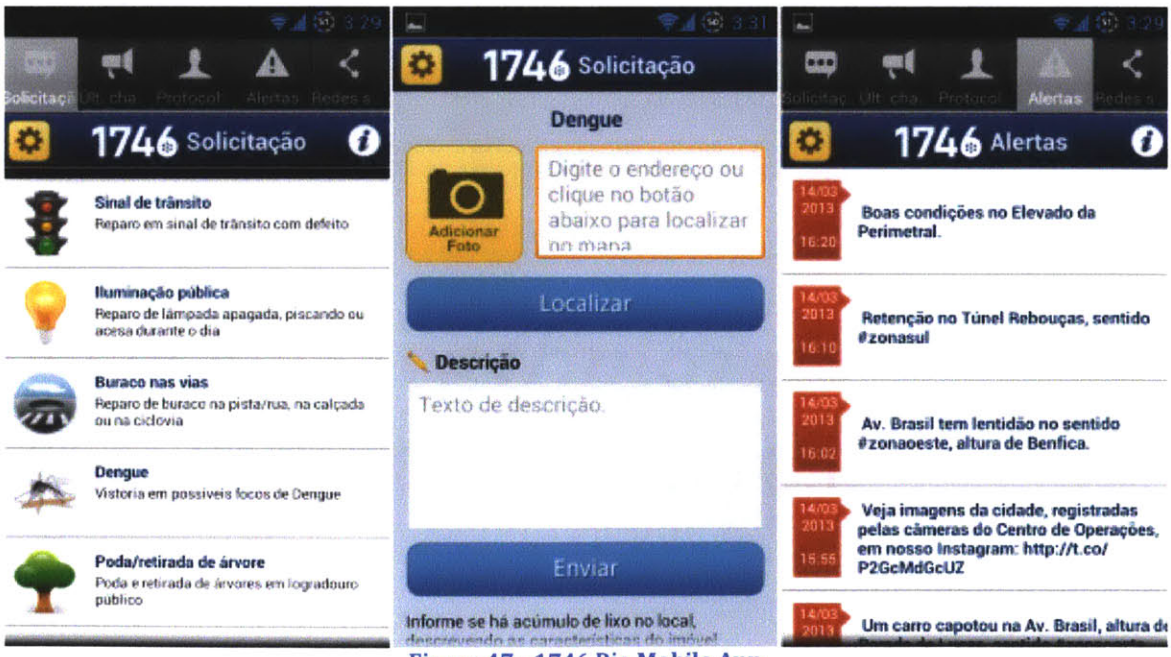

Figure 47 - 1746 Rio Mobile App
Source: https://play.google.com/store/apps/details?id=br.com.golmobile.canal746&hl=en

Economy

To boost its economy and in particular, to promote the growth of its ICT sector, the city implemented "rio-digital.com", a collaborative web project which maps the city's digital companies, incubators, investors, co-working opportunities, etc. (see Figure 48 - Rio-Digital.comFigure 48).

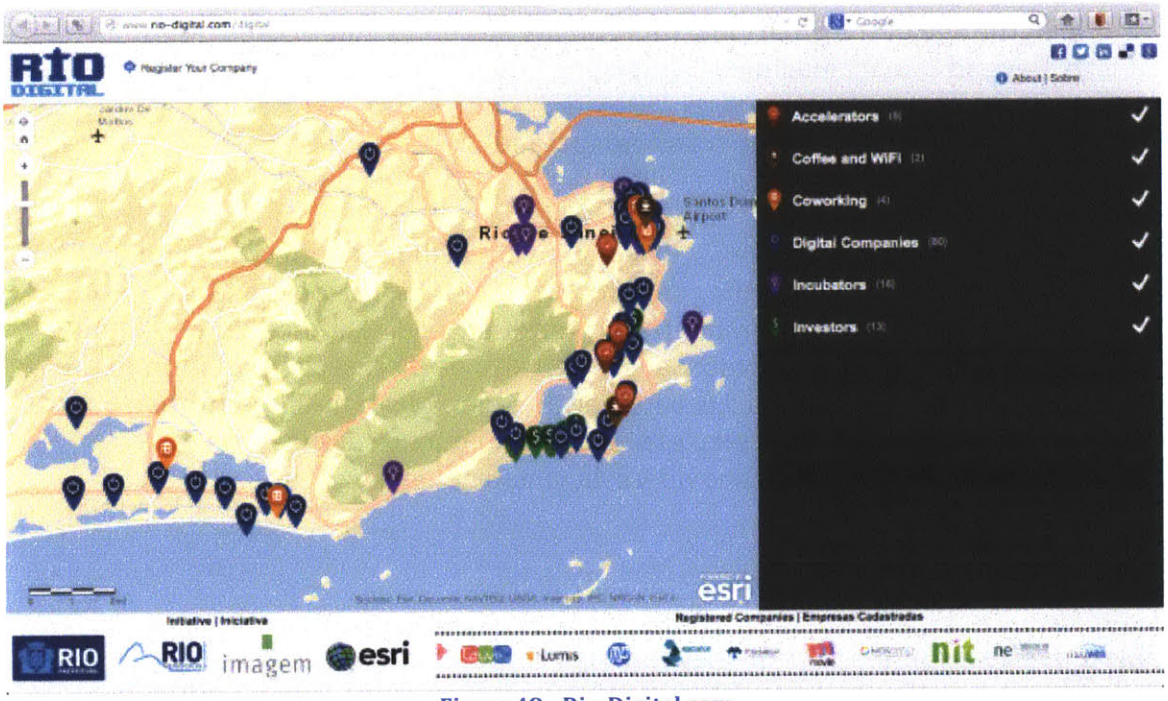

Figure 48 - Rio-Digital.com
Source: http://rio-digital.com/digital

Cisco (2012b) announced news to implement the "Cisco Rio Center of Innovation", which aims to develop local solutions for urban development, sports and entertainment, public safety and security, education, health care, and energy. For example, Cisco sees opportunities for its technologies to be further applied in internet services and government operations, using network-based innovation to enhance sports and entertainment, integrating security systems through an internet protocol, etc.

Chapter 4 – Findings and Discussion

In this chapter, the findings of the case studies – i.e. the cities' concepts and perceptions of "smart cities" and their different approaches gathered through primary and secondary data sources – are first assessed against the four main theories of being a "smart" city:

a. In the age of the Smart Machine: Smart Machines and Organization;
b. Beyond "Smart Machines": Engaging Communities, Organizations & Businesses;
c. Cities that Learn, Relearn and Adapt; and
d. Investing for the future.

Following this, the different approaches of each city will be synthesized, and analyzed in relation to the specific conditions of the cities, i.e. focus areas, underlying motivations, partnership frameworks, engagement models, etc. Some findings on the cities' different approaches will also be discussed in relation to the nature of the "smart" initiatives, i.e. whether these are location-based infrastructure, community-focused initiatives, etc., as well as the influence of the types of technology and the technology providers' business models.

Case Study Findings: An Overview

Table 1 overleaf summarizes the key findings of the six cities examined, with examples of "smart" initiatives listed. As there are numerous "smart" initiatives involved in each city, these examples are non-exhaustive and serve only as illustrations of the cities' specific approaches.

Table 1 -Summary of Key Findings

	BOSTON	SAN FRANCISCO	STOCKHOLM	AMSTERDAM	SINGAPORE	RIO DE JANEIRO
General Features						
Specific agencies / "smart" platforms examined	MONUM DoIT	SF MOCI SF Environment	Stokab SRS / City Planning Administration	AIM / ASC	IDA EDB LTA	COR
Nature of agencies examined	Government	Government	Government	Non-Profit Foundation	Government	Government
Core focus areas of agencies examined	City Innovation, ICT	City Innovation, Environment / Sustainability	ICT, Planning / Sustainability	Economic Development & City Innovation	ICT, Economic Development & City Innovation, Transportation	Integrated City Management (Transportation, Emergency response)
Theory A - In the age of the Smart Machine: Smart Machines and Organization						
Examples of "Smart Machines" Automation	Data integration and cross-referencing	No data	No data	No data	Traffic prediction	Weather prediction and emergency alerts
Organizational change: response to the use of "smart machines"	Boston city departments: Some organizational change at small, incremental scale, building on existing structures and processes	SF Environment: No organization change as yet, but recognition of the need and benefits	No data	No data	LTA: Some organizational change at small, incremental scale, building on existing structures and processes JLD / EDB: No organization change as yet, but recognition of the need and benefits	COR: Reorganization of city functions

		BOSTON		SAN FRANCISCO	STOKHOLM		AMSTERDAM		SINGAPORE		RIO DE JANEIRO
Theory B - Beyond "Smart Machines": Engaging Communities, Organizations, & Businesses											
Organizational change: Creation of new agencies / departments entities to lead "smart" efforts		MONUM: New city-level agency championing innovation through partnerships, with self-capacity and responsibility for innovation, new systems & policies		SF MOCI: New city-level agency championing innovation through partnerships, with self-capacity and responsibility for innovation, new systems & policies	STOKAB: New city-level agency providing backbone infrastructure through innovative policies		AIM: New city-level agency championing adoption of ICTs in innovation through a facilitator role in engaging partnerships		IDA: New agency-level department championing innovation through partnerships, promoting innovation, new systems & policies EDB: New agency-level department championing innovation through a facilitator role and incentivizing entrepreneurship		COR: New city-level agency, involving major reorganization of existing agencies, active in using ICTs, innovative and integrated processes.
Collaboration & leveraging human capital: Examples of initiatives		Discover BPS / School Choice (MONUM, DoIT)	Community PlanIT (MONUM, BPS)	Unhackathon / Summer of Smart, etc., (SF MOCI, City Departments)	Network Infra-structure (STOKAB)	Stockholm Royal Seaport	Smart Work Centers	Climate Street, Amsterdam (City of Amsterdam)	Jurong Lake District (EDB, IDA, etc.)	UP Singapore (IDA, EDB, NEA: data providers)	COR
Partner(s)	Tech providers / Private sector businesses	Code for America	-	Local non-profit organizations e.g. @GAFFTA (funding & organizer)	STOKAB functioned as the city agency and technology infrastructure provider	Fortum, Ericsson, Envac, etc.	CISCO; Facility owners / operators e.g. hotels, airports, etc.	Local technology providers	IBM (grant); Technology providers will be engaged to address problem solutions identified by city agencies	UP Singapore (organizer)	IBM
	Research institutions	-	Emerson College served as the technology provider	-	-	Swedish ICT	-	-	-	National University of Singapore	-
	Community groups / Public individuals	-	Community feedback on education system	Public / community input on improving city services through technology & apps	-	Resident stakeholders will potentially be involved in data collection e.g. energy consumption	-	Stakeholder businesses & entre-preneurs	-	Public / community input on improving city services through technology & apps	-

	BOSTON	SAN FRANCISCO	STOCKHOLM	AMSTERDAM	SINGAPORE	RIO DE JANEIRO
(cont'd from above) "Bottom-up", "Middle-out" and "Top-down" approaches to "smart" initiatives	Citizens Connect: "Middle-out" approach where city government provides some definition of specific issues or problems, facilitates opportunities for ideas and technology to respond openly	Unhackathon / Summer of Smart: "Bottom-up" approach, where stakeholders / community, instead of city government, initiate "smart" projects and grassroot efforts surface ideas & technologies that find application Living Innovation Zone / CleanTech: "Middle-out" approach where city government provides some definition of specific issues or problems, facilitates opportunities for ideas and technology to respond openly	Stockholm Royal Seaport: "Middle-out" approach where city government provides some definition of specific issues or problems, facilitates opportunities for ideas and technology to respond openly	Climate Street: "Middle-out" approach where city government provides some definition of specific issues or problems, facilitates opportunities for ideas and technology to respond openly	Jurong Lake District: "Middle-out" approach where city government provides some definition of specific issues or problems, facilitates opportunities for ideas and technology to respond openly Traffic Management: "Top-down" approach where city government initiates "smart" projects, setting goals and specifying technologies and framework	COR: "Top-down" approach where city government initiates "smart" projects, setting goals and specifying technologies and framework

	BOSTON	SAN FRANCISCO	STOCKHOLM	AMSTERDAM	SINGAPORE	RIO DE JANEIRO
Theory C - Cities that Learn, Relearn and Adapt						
Continual Learning	G7 network and open data (Socrata) platform: Part of a network of cities actively exchanging ideas & solutions, using common platforms	Meeting of the Minds, CAFEET, etc. conferences: Sharing at local and international conferences	Professional Study Visits: Hosting learning visits for local, regional and international groups	"Smart Stories" publication and knowledge website: Providing detailed documentation and results of "smart" initiatives ASC hosted visits: Hosting learning visits for local, regional and international groups	IDA: Hosting learning visits for local, regional and international groups Singapore World Cities Summit, IDA, EDB, etc.: Sharing at local and international conferences	No data
Use of Metrics	Citizens Connect action research: Evaluates organization and processes, in addition to using metrics for their "smart" initiatives	SF Park: Aware of the use of metrics in their "smart" initiatives, some aspects not implemented yet (e.g. data collection)	Stockholm Royal Seaport new sustainability unit: Evaluates organization and processes, in addition to using metrics for their "smart" initiatives	ASC: Uses metrics to assess the effectiveness of their "smart" initiatives.	No data	No data
Use of Feedback Loops	No data	Charge Point: Uses feedback loops within their "smart" initiatives to fine-tune the intiative and inform internal processes	Stockholm Royal Seaport: Uses feedback loops, extended to provide critical review and willingness to abandon technology and set up of "smart" initiatives	Decentralized energy production (review of policies): Uses feedback loops within their "smart" initiatives to fine-tune the initiative and inform internal and external processes and policies, including those of other departments and agencies	Traffic management (long-term landuse-transportation planning): Uses feedback loops within their "smart" initiatives to fine-tune the initiative and inform internal and external processes and policies, including those of other departments and agencies	No data

	BOSTON	SAN FRANCISCO	STOCKHOLM	AMSTERDAM	SINGAPORE	RIO DE JANEIRO
Theory D - Investing for the Future						
Capital costs & ROI approach	MONUM: City agency does not provide funding, but seeks and obtains funding from other sources (e.g. higher tier government, foundations) to facilitate "smart" initiative	SF Park: City agency does not provide funding, but seeks and obtains funding from other sources (e.g. higher tier government, foundations) to facilitate "smart" initiative	No data	AIM: City agency does not provide funding, but provides existing physical assets and / or manpower resources to mobilize & organize collaborative efforts between city departments and / or technology providers	EDB Living Lab Fund: City agency provides seed or partial funding for small-scale prototype, in partnership with technology providers IDA: For some projects such as JLD, city agency, together with partner agencies, provide funding and infrastructure. For some collaborations with technology providers, some funding is provided, while other projects involve manpower resources and coordination efforts	COR: City agency provides full capital funding for "smart" initiative
Directly monetizing "smart" initiatives: Sale of city data	Open data approach	Open data approach	Open data approach	Open data approach	Open data approach. Some data (e.g. traffic prediction results) are restricted to research institutions only	No data
Long-term wider benefits	No data	SF environment: Meeting environmental sustainability goals (e.g. reducing energy use / CO2e)	Meeting environmental sustainability goals (e.g. reducing energy use / CO2e) Economic benefits for technology provider(s) in up-scaling and commercializing "smart" solutions	Meeting environmental sustainability goals (e.g. reducing energy use / CO2e) Economic benefits for technology provider(s) in up-scaling and commercializing "smart" solutions	Economic benefits for technology provider(s) in up-scaling and commercializing "smart" solutions	No data

Theory A - In the age of the Smart Machine: Smart Machines and Organization

Assumptions: The "smart city" involves the use of ICTs for automation and intelligent functions, and is also "smart" about the way its processes, organization and governance can be reorganized to take advantage of these technologies.

An assumption for "smart" cities, based on the theory of "smart machines", is that these cities employ the use of ICTs for their automation and intelligent functions to yield benefits compared to conventional or traditional methods. While this has been evident through a few city functions from the case studies, in particular, COR in Rio de Janeiro, not all of the cities directly employ the use of ICTs as "smart machines", nor see this analogy as defining their concepts of being a "smart" city.

In addition, whilst the theory of informating suggests the potential benefits of reorganization to take advantage of the ICTs, for some of the examples where "smart machines" were employed, reorganization and changes in workflow did not appear to be a clear feature. On the other hand, reorganization of a different nature was observed at a broader level, i.e. mainly at the city or city-agency level, to specifically promote and facilitate innovative "smart" solutions through the use of new technologies.

"Smart" Machines

The application of ICTs in "smart" city functions can be seen most clearly from the examples of Rio de Janeiro, as well as Singapore and Boston, where machine automation and intelligence are harnessed for speedier workflow and more accurate and reliable results.

In Rio de Janeiro, COR's weather prediction system, based on IBM's "Deep Thunder", takes into consideration "city-specific soil composition data, hydrology models, urban flooding models, topographical data, population data and land use data" to predict both the weather and the impacts of weather (Dillow 2011). According to Treinish et al (2012), the accuracy of the forecast, averaged over all rain events from 26 May 2011 through 8 January 2012 by 12-hour periods for all categories, ranged from 91.8% to 93.6%. For the same rain events, assuming a +/- 5mm tolerance at each category threshold, the accuracy ranged between 95.6% and 97.1%. The results are disseminated within COR through visualized data in the form of tables, charts, as well as 2D and 3D animations, to assist decision-making.

Singapore's trial "Traffic Prediction Tool" developed with IBM involves active prediction of traffic flows. According to a LTA official interviewed, the use of algorithms allow the prediction of future traffic conditions, whereas conventionally, traffic managers are limited to information on current and past conditions. Thus, this "smart" capability extends the function of traffic management to anticipate future traffic conditions in advance and respond accordingly by putting measures

ahead of time. This prediction tool is reported to be 85% accurate in predicting traffic volume (Hicks 2010) and the LTA official highlighted that the system can predict 30 minutes in advance, minimizing traffic disruptions and reducing economic costs resulting from traffic delays.

Another example of improved workflow arose from Boston's DoIT data warehousing and integration efforts. According to Lane (2013), with the integration and sharing of the city's data and GIS, city departments are "now able to easily identify and analyze problem(s)" such as properties by coordinating and maintaining a master database with address points. Compared to previously where information was mostly conveyed by word of mouth, Lane highlights that the integration has now allowed cross-referencing of different data such as crime data, the city's Constituent Relationship Management System, public health records, code violation records, etc., allowing "hotspots to be identified and mapped". Other improvements include departments' service delivery standards in the management of code violations, fleet management, etc. with the use of business analytics tools.

The above examples of "smart machine" functions raise the question whether there are specific characteristics of city-scale functions that lend themselves more to automation. Whilst the study only revealed three examples, and further investigation will be needed to compare the results of "smart machine" functions against conventional methods, these examples appear to share some common features that may draw further lessons and application for planners.

First, the functions involve the use of data, and more specifically, require the setting up of prerequisite infrastructure and processes for data collection, integration, interpretation and analysis, etc. For example, for Rio de Janeiro and Singapore, the necessary infrastructure (e.g. sensors, CCTV, car-based GPS units, weather stations, etc.) were first put in place to collect data on current conditions (e.g. traffic, weather) from various sources, before being transmitted, organized and integrated (e.g. data warehousing) for their "smart" functions, often involving sophisticated algorithms for prediction and / or visualization to facilitate analysis. Second, these functions appear to be based around shorter-term city management operations that display some structure of behaviors and rules. For example, Rio de Janeiro's emergency responses and alerts are linked to the city's defined levels of threats identified through the weather, flood and landslide prediction functions. Third, the integrated processing of data from multiple sources, analogous to overlaying different sets of data, has the potential to lead to the discovery of new or improved functions and capabilities. As seen in Rio de Janeiro's example, the integration of weather prediction, traffic management and emergency response is unprecedented and has changed the city's effectiveness in response. In Boston's case, the cross-referencing of different city datasets has opened up opportunities for new processes such as identifying problematic "hotspots".

Apart from these examples, the question remains - are there any other opportunities for cities to automate their functions, for example, in terms of organizing and

integrating data from different sources, data analytics, etc.? What are the implications for city planning? In particular, can similar "smart machine" automation be applied for longer-term city planning and management functions? Chapter 5 aims to address some of these questions.

Complementing "Smart" Functions with Organizational Change

In terms of embracing reorganization, the cities examined can be categorized as shown in Table 2.

Organizational change in response to "smart" functions		
No organizational change as yet, but recognition of the need and benefits.	*Some organizational changes at a small and incremental scale, building on existing structures and processes.*	*Reorganization of city functions*
San Francisco Environment; Singapore Jurong Lake District / EDB	Boston city departments; Singapore LTA	Rio de Janeiro COR

Table 2 - City / Agencies: Organizational change in response to "smart" functions

For Rio de Janeiro, the implementation of COR involved the integration of various city departments and private utility companies, as well as introducing new work processes to ensure 24-hour shift operations. According to COR Chief Technology Officer Alexandre Cardeman in an interview with The Daily Beast (2011), re-organization and a unified workflow between agencies at such a scale and degree is unprecedented, and integral with the new "smart" functions:

> *"Nowhere else do you have the guy in charge of the train system working with everyone else in the same room. So when there's a car accident, we can zoom in and read the license plate, we can already see where the closest Municipal Guard is, start to divert traffic and alert the nearest ambulance by GPS, because we're all integrated."*

Rio de Janeiro's reorganization of its city functions could be attributed to the need for integration with its new "smart" functions; a system where "smart" functions cannot function without organization change, and vice versa. For example, having predictive capabilities of impending landslides will be ineffective unless the information is relayed quickly and effectively to emergency response agencies who are close at hand and who can coordinate amongst each other. Another pre-requisite appears to be the strong commitment of resources, vis-à-vis major investments in the system, as well as the agreement of all city departments to accept new work flows, processes and command structures under one roof.

For the other cities examined, it appears that most agencies prefer an incremental approach to change. This is especially so when the "smart" initiatives are prototypical in nature, and may require further time and resources to develop. For some cities, existing agencies and departments may already have established expertise and processes; this provides on one hand a useful starting point to extend current processes, but on the other hand some resistance to accept new drastic changes.

In Boston's case, Osgood (2013) revealed that in implementing the "Street Bump" initiative, changes were needed for some processes and management practices of the Public Works Department, some of which involved "doing things in a completely foreign way". Hence MONUM ensured close collaboration by aligning interests with line agencies, and taking incremental steps to develop new initiatives. Lane (2013) describes how the introduction of ICTs has required coordination within departments, especially with the older workforce.

For Singapore's "Traffic Prediction Tool" initiative, there were no organizational changes within LTA's traffic management unit. According to the LTA official interviewed, the new predictive functions were added as an extension to the existing departmental workflow and processes. This is given the existing base knowledge and expertise in traffic management of the staff involved, which are required in the trial of the new predictive applications. Thus, this model involves an incremental approach to changes in processes without changes to organization, based on the premise of a skilled workforce that is able to test and adopt new functions.

Some cities have identified opportunities for greater integration in the application of "smart" initiatives across existing organizational structures, but have yet to do so. These cities recognize that "smart" initiatives are cross-disciplinary in nature and require holistic integration.

For example, Miller (2013) describes San Francisco's situation where:

> *"...smart technologies can be applied to nearly every aspect of sustainability in San Francisco- from waste, to buildings, to energy, and more. The next step is to integrate these into a complete system".*

Similarly, for Singapore's Jurong Lake District, the EDB official interviewed highlighted the importance of an integrative dimension across city agencies in the implementation of "smart" initiatives, which require structural organizational change:

> *"... There is need for more coordination, for example, who is the person or body with the mandate to oversee or drive these efforts? Structural change is necessary. Technology is relatively easier to develop compared to organization change, and hence technology is not the limiting factor..."*

In this case, the EDB official explained, this was mitigated by the formation of a new government steering committee chaired by a Permanent Secretary of a ministry, and comprising the CEOs of various city agencies. Although this new committee allows a high-level oversight that maintains strategic focus and ensures inter-agency agreement and support, it largely retains the roles and structures of individual agencies.

Whether technology is "relatively easier" also reflects the priorities and capacities of city agencies to adopt and adapt to technology, in relation to their organizational processes and functions. Notwithstanding that cities like Rio de Janeiro have shown organizational change, further investigation will be needed to evaluate the extent to which city agencies and departments have adapted themselves to "informating". For example, on one level, different city agencies may be streamlining their processes through harnessing ICTs and reorganizing themselves under an integrated hierarchy. On another level, these agencies could be creating entirely new innovative functions and city services based on the "smart" automation, and breaking silos of traditional organizational structures in the process.

The next section discusses a different approach to organizational change, whereby cities create new entities as part of their "smart" efforts, with the motivation to drive innovation through collaborative partnerships.

Theory B - Beyond "Smart Machines": Engaging Communities, Organizations & Businesses

Assumptions: The "smart city" involves a collaborative process where city governments engage communities, businesses, research institutions, etc. as partners in a framework that drives innovation and transformation.

All six cities examined created new city-level agencies or city agency-level departments. Apart from Rio de Janeiro, where the new agency revolved around the COR "smart machine" concept, new agencies or departments in the other five cities were evidently formed to lead the cities' "smart" efforts based on collaborative partnerships. This reflected the theories and ideas that "smart cities" involve a collaborative process where city governments engage communities, businesses, research institutions, etc. as partners in a framework that drives innovation and transformation.

Creation of New Agencies to Lead "Smart" Efforts

Table 3 categorizes the cities examined in terms of the nature of the newly created agencies / departments, reflecting their different approaches and motivation.

Creation of new agencies / departments: Characteristics		
New city-level agency or department. Champions adoption of ICTs in innovation through a facilitator role in engaging partnerships.	*New city-level agency or department. Champions adoption of ICTs in innovation through partnerships, with self-capacity and responsibility for innovation, new systems & policies.*	*New city-level agency, involving major reorganization. Active in using ICTs, innovative and integrated processes.*
Amsterdam AIM; Singapore EDB	Boston MONUM; San Francisco MOCI; Stockholm STOKAB; Singapore IDA	Rio de Janeiro COR

Table 3 - Creation of new agencies / departments: Characteristics

Examining some of these newly created agencies / departments, Boston's MONUM was created in 2010 to "speed the rate of municipal innovation" based on principles of "collaborating with constituents, focusing on the basics of government, and pushing for bolder ideas" (MONUM 2012).

For San Francisco, the city created a new position of "Chief Innovation Officer" and the Mayor's Office for Civic Innovation, which is responsible for the city's innovation initiatives including open data. This new organization, according to Miller (2013), is part of the city's "working to update its operations for the digital age". Hence, all "smart" initiatives are centrally managed on an overall basis, while individual projects are managed and implemented by various departments including the Municipal Transportation Association, the Department of the Environment, the Planning Department, the Public Utilities Commission, and others.

In Amsterdam, AIM was created in 2006 and saw further reorganization in January 2013 where it became part of the Amsterdam Economic Board. While it was instrumental in initiating the Amsterdam Smart City (ASC) program in 2009, its role is largely facilitative in nature, focused on maintaining the common platform where different partners are matched and engaged.

At the city agency level, organizational changes may involve the creation of new units within existing structures. For example, Singapore's IDA created its "Smart Cities Program Office" in 2011 to "lead the Smart Cities thrust", which focuses on:

> *"...the development of infocomm-based integrity networks, capabilities and solutions for urban environments with a systems-of-systems approach that enables Whole-of-Government synergies and integrated insights, which will contribute to the optimization of key national resources across interdependent and inter-related city systems. It is not limited to technology but more encompassing of other aspects such as governance, procedures and business*

policies (e.g. sharing of data, insights, infrastructure and resources)." – IDA 2013a.

Like IDA, Singapore's EDB also formed its "Urban Solutions" cluster to provide dedicated focus on the emerging field of "smart cities" as an economic sector. For example, investments in new technologies and start-ups which offer "smart" solutions are incentivized and managed through this cluster.

"Smart", Better Governance, Engaging Citizens and Better Delivery City Services

An underlying motivation in their pursuit of "smart" initiatives, given the government nature of many of the city agencies / departments examined, is to achieve "smart" and better governance. This often involves improving the delivery and efficiency of city services, careful use of resources, engaging citizens, more transparency and accountability, etc.

For example, through the "Boston About Results" web portal, the city publishes its regular "scorecard" reports:

> *"These reports are tools for city officials and residents to know what city agencies are doing, how well they are doing it, and where they can improve. Collecting and sharing this data keeps city agencies responsible and accountable while striving to improve quality of life for all Bostonians."* - City of Boston (2013b).

The "scorecard" includes indicators on the number of web hits for city web sites and services, the number of permits and licenses issued online, percentage of streetlight outages addressed in 10 business days, percentage of graffiti removal calls responded to within 36 hours, number of park maintenance requests completed, etc. Such reports and transparency in governance are facilitated by the use of ICTs.

The Boston "Citizens Connect" initiative has been relatively well-received by the community, with positively rated apps receiving an overall 4.3 out of 5-star rating in Google Play and 3.5 out of 5-star in the iTunes App Store[5]. Some 5-star reviews from app users are shown below, reflecting for example, how receptive members of the community have been in their own empowerment and ease of direct communication with city workers, the desire that such initiatives are replicated in other cities, compliments on the speedy response by city workers, as well as how such an initiative can contribute to the cleanliness of the city.

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[5] Boston Citizens Connect, in iTunes Preview, https://itunes.apple.com/us/app/boston-citizens-connect/id330894558?mt=8, accessed on 12 February 2013, and in Google Play, https://play.google.com/store/apps/details?id=gov.cityofboston.citizensconnect, accessed on 12 February 2013.

"A big step forward for Boston - This app is a big step forward for the city of Boston as it enables people to submit work requests very efficiently. I submitted a few myself and we'll see if they get resolved. I have submitted some through the website and they have been successful. I really like that Boston is developing these apps because it really empowers citizen and can let users improve the city in real time because they can communicate directly with the workers." by someiphoneuser5 (iTunes).

"It is great app. Working good to me. Hope every city will have such app. Good luck." by A Google User (Google Play).

"Excellent, Quick Responses by Boston - There was a lot of trash on my East Boston street. With this app I took a picture of it and within 2 hours Boston public works was cleaning the trash out of the street! The app is well designed and easy to use. Download it and help keep Boston clean!" by MattFow (iTunes).

However, there are also negative reviews, for example, those that are critical about the lack of action or the slow speed of response, or the nature of the city's response:

"An empty bin to complain to - If you want a record of excuses of why Menino's people will not do anything, this is the app for you. If you were hoping to actually have someone do something about requests for services, this is useless." by Hoolese (iTunes).

"App is great, city is slow - App works just fine. Its great to be able to alert the city to issues. Now if only Boston would act in a timely manner..." by A Google User (Google Play).

"Made a legitimate complaint and the city's response was to dismiss it rudely despite my being complimentary of the city." - A Google User (Google Play).

Notwithstanding the negative reviews, the Boston "Citizens Connect" initiative clearly provides a new technological avenue for citizens to submit and track reports in real-time. Ms Claire Lane, from the city's DoIT, cited another similar example where a citizen's request for a waste management recycling sticker through the city's Constituent Relationship Management System met with a prompt response within 15 minutes by a city service team, whereas a typical request would take up to 3 days (Lane 2013). These "smart" initiatives have evidently positively impacted the city's citizen-government relationship, where Lane described, "a recurring theme is citizens' engagement... and for the city to deliver better services". There is greater access to and transparency on city services, and the delivery of services has improved.

For Boston's "Community PlanIT" initiative which engaged the community in providing feedback on the BPS school performance metrics and accountability

system, Gordon (2013) highlighted that the feedback generated through the use of the engagement game platform was "significant", provided "evidence of the effectiveness of the general approach" and "surpassed expectations of non-technological approaches". This reflected the success of the initiative as compared to traditional engagement methods.

Another dimension of community engagement involves the process of conceptualizing and developing the "smart" initiatives. For example, in Boston's case, this is done at two stages. At the idea sourcing stage MONUM keeps an "open door" to community feedback and ideas from anyone, including members of the community, students, researchers, etc. At the product development stage, for example, for the apps, MONUM conducts multiple beta tests involving citizen volunteers. According to Osgood (2012), these volunteers "end up being the greatest advocates for the apps", telling others of the initiative "by word of mouth".

In San Francisco's case, as summarized by Miller (2013), technology is used:

> *"...to promote innovation, information sharing, collaboration among the public and private sectors, as well as our residents. This will allow us to make our city operations more efficient, save money, and further engage our residents in our sustainability efforts."*

For Singapore, its efforts to provide government e-services were well-received, reflecting the quality and effectiveness of its initiatives. According to IDA (2009), 8 out of 10 users were "satisfied with the overall quality of e-services", 9 out of 10 users "would recommend others to transact with the Government through e-services", and 8 out of 10 users were "very satisfied with the level of clarity and usefulness of information published online on Government policies, programs and initiatives".

While the above examples illustrate how city services can be effectively delivered using ICTs, one measure not covered in this study, due to lack of data, is the relative effectiveness of these new services against traditional methods of delivery. For example, while the "Citizens Connect" or other similar web / mobile app provides a new channel for requesting a service, a more holistic assessment of improved governance or service-delivery will require cities to assess the impact of the new service against (i.e. impacts attributed to the new service), and together with existing channels (i.e. combined impacts). If, for instance, the impacts attributed to the new service are relatively small or negligible, an ensuing question will be the cost-effectiveness of this "smart" initiative. In addition, even the relative success of one or two apps or e-services may not reflect the overall picture of governance. Hence, a broader and pertinent issue is the formulation of metrics that accompany the implementation of "smart" initiatives, together with consideration on targets and objectives. This is discussed in a later section.

Collaboration & Leveraging Local Human Capital

In general, all the cities examined implemented their "smart" initiatives through collaborative partnerships, leveraging local human capital - i.e. community groups, research institutions, technology providers, businesses, government agencies, etc. - to generate ideas and innovation. The extent and nature of the partnerships differ between cities and their initiatives, as illustrated in Table 4.

According to a city official interviewed, Amsterdam's "smart" efforts, led by AIM, are based on the triple-helix model of co-operation between the city, research institutions and industries. This model, Leydesdorff & Deakin (2010) explains, taps on the dynamics of the "intellectual capital of universities, the wealth creation of industries, and the democratic government of civil society" and is a product of "carefully constructed" policies that allow cities "to be more intelligent and smart". Hence, AIM serves as a platform for such collaboration that draws together government agencies, technology providers and companies, and communities; as the central "contact point", it matches the needs with the ideas and capabilities of various partners and facilitates the formation of project teams and implementation of pilot initiatives.

For Boston, Cohen's remark that "one of the under-explored components of smart cities is how they enable and attract smart citizens to innovate solutions" (Cohen 2012c) was echoed by Lane (2013), who identified that an opportunity and continual challenge is how the city can "reach out to smart people in the city and region to ask them, describe challenges and leverage on their expertise". This reflects the city's recognition on the enormous potential to be tapped upon.

The development of Stockholm's Royal Seaport is a collaborative effort between the city and developers, stakeholders, technology providers and academia, who are involved in different aspects of the project. For example, several technology providers and research institutions (i.e. Fortum, Ericsson, Envac and Swedish ICT) lead research and development projects in the application of ICTs, "smart" grid and "smart" waste collection, testing and validating "new sustainable solutions... to be developed into full-fledged business models and commercialized concepts" (Stockholm Royal Seaport 2013).

Examples of different partnership frameworks			
"Smart" Initiative *City agency / department(s)*	*Technology Provider(s) / Private Sector Business(es)*	*Research Institution(s)*	*Community Group(s) / Public Individual(s)*
Network Infrastructure, Stockholm Stokab	Stokab functioned as the city agency and technology infrastructure provider	-	-
COR, Rio de Janeiro (Cross-agency partnership)	IBM	-	-
Traffic Management, Singapore LTA	IBM	-	-
Jurong Lake District, Singapore (Cross-agency partnership involving EDB, IDA, etc.)	Technology providers will be engaged to address problem solutions identified by city agencies	-	-
Smart Work Centers, Amsterdam	CISCO; Facility owners / operators e.g. hotels, airports, etc.	-	-
Discover BPS / School Choice, Boston (Cross-agency partnership involving MONUM, DoIT, BPS)	Code for America	-	-
Traffic Management Research, Boston	IBM	Boston University	-
Climate Street, Amsterdam City of Amsterdam	Local technology providers	-	Stakeholder businesses & entrepreneurs
Unhackathon / Summer of Smart, etc., San Francisco (Cross-agency partnership involving SF MOCI, City Departments)	Local non-profit organizations e.g. @GAFFTA (funding & organizer)	-	Public / community input on improving city services through technology & apps
Community PlanIT, Boston (Cross-agency partnership involving MONUM, BPS)	-	Emerson College served as the technology provider	Community feedback on education system
UP Singapore, (Cross-agency partnership involving IDA, EDB, NEA as data providers)	UP Singapore (organizer)	National University of Singapore	Public / community input on improving city services through technology & apps
Stockholm Royal Seaport, Stockholm	Fortum, Ericsson, Envac, etc.	Swedish ICT	Resident stakeholders will potentially be involved in data collection e.g. energy consumption

Table 4 - Examples of different partnership frameworks

For Singapore, IDA's projects mainly take a sectoral approach in collaborating with city agencies, technology providers and research institutions (Tay 2013a). In the implementation of ICT infrastructure, one of the approaches that IDA takes is a "match-making" role, facilitating partnerships between industry technology providers and bringing requirements together. For example, the implementation of the NFC system involves collaboration with a consortium of banks, e-payment providers as well as third party technology platforms. For the Jurong Lake District initiative, IDA, EDB and the city agencies fund and undertake the implementation of common infrastructure, such as the fiber networks, wireless access facilities and data sensors, providing the prerequisite infrastructure for partners to build solutions upon.

The use of hackathons, or similar programs to encourage the use of the city's open data, is a common initiative used by several cities (e.g. San Francisco, Boston, Amsterdam, Singapore, Stockholm) to engage new partners and seek innovative ideas. According to Nath (2012), through the "Summer of Smart" hackathon organized with GAFFTA, San Francisco had a total of 5,000 participants, 10,000 hours of civic engagement, and 25 apps were created. In Boston's case, the city sees hackathons as a potential source of new ideas, in particular, for data visualization and analytics that lead to "better services delivery" (Lane 2013). At a recent Urban Protoyping (UP) event held in January 2013 organized by UP Singapore in partnership with Earth Hour and the local National University of Singapore (NUS), over 120 people participated, contributing over 2,000 hours of work based on an "Energy & Environment" theme, and an app prototype was selected for further development (UP 2013).

The examples described above, as well as those shown in Table 4, illustrate a diversity of partnership approaches. One observation is that all "smart" initiatives required the involvement of technology provider(s), however, many of them do not involve research institutions and / or the community. Even amongst the research institutions involved, only Swedish ICT was engaged in research and test-bedding as part of the Stockholm Royal Seaport initiative; Emerson College served as the technology provider with its method for community engagement under the Community PlanIT initiative, and the National University of Singapore supported the hackathon event through its student / researcher participants and its commitment to incubate the resulting prototypes. While the above list of examples may not be representative of all "smart" efforts, nonetheless, this raises questions on the role and involvement of research institutions that requires further investigation. For example, are cities more willing to partner technology providers more than research institutions due to the availability and readiness of technology? Are there constraints faced by cities, in their implementation of initiatives, to meet substantiated objectives that technology providers are able to better fulfill compared to research institutions? In a broader sense, what considerations are there in the way cities structure their partnerships?

First, the nature of the implementing agency appears to be a major factor. In the case of Stockholm's Stokab, the agency functioned both as the city agency and technology infrastructure provider for the fiber network; hence the initiative did not involve a partnership model. However, such cases of agencies having the requisite technological and implementation expertise may be few. In most of the other examples, whilst most agencies appeared to understand the systems and technology that were needed to address their issues, they had to rely on the expertise of technology providers to implement them, whether it is coding or app-making (e.g. Boston School Choice) or weather prediction (e.g. COR).

Second, the expertise of the technology provider vis-à-vis its specific business model appears to be another factor. For example, in the case of COR, there may be limited number technology providers or businesses like IBM that may be able to provide a similar extent of integrating analytics capabilities, software and hardware. If the core technology is proprietary or a critical segment of their business (e.g. CISCO's TelePresence Smart Work Centers) technology providers may also not see the need to be part of a collaborative framework. Similarly, technology providers may be keen to form partnership consortia if their technologies and focus areas are deemed to be complementary, i.e. without the risk of business cannibalization. In some situations, such as in the case of Stockholm Royal Seaport, individual firms within the consortium appear to focus on different areas of technology, e.g. Fortum on energy, Ericsson on telecommunications, and Envac on waste collection.

Third, the nature of each project appears to be a major determinant. For example, where the "smart" initiative serves a specific function that is considered to be solely a city service (e.g. traffic management in Singapore, weather prediction and emergency response in Rio de Janeiro), city agencies may not perceive the need for community groups or the public to play any role in the implementation or operations of the initiatives. For example, city agencies may be mindful of the risks at hand and view such mission-critical services more seriously; traffic delays amounting to economic costs in the millions or emergency and security responses that deal with lives may weigh more heavily compared to crowdsourcing community inputs for pothole repairs or providing real-time public transit information. In addition, a city agency which has a clear idea of the objectives and technologies desired (e.g. setup of Rio's COR to address emergency response in relation to floods and landslides) may be more focused in selecting specific partners, compared to where a wide range of ideas are being sought (e.g. crowdsourcing new ideas and innovation through hackathons, engaging a wide range of technology providers using open problems for Singapore's Jurong Lake District). Similarly, if the "smart" initiatives encompass elements of prototyping and test-bedding (e.g. Stockholm Royal Seaport), the partnership may be broader to include a wider range of technology providers and / or research institutions. Thus, the nature of the project may influence city agencies' perceptions on the type of collaboration framework.

Partnership Framework: "Bottom-up", "Middle-out" and "Top-down" Approaches

The cities' partnership frameworks examined above begin to expose the nature of the collaborative models, in particular, whether the "smart" initiatives adopt a "bottom-up", "middle-out" or "top-down" approach, and to what extent different partners (e.g. members of the public / community) are engaged or involved in the initiation of the projects. Examples are shown in Table 5.

"Bottom-up", "Middle-out" and "Top-down" approaches to "smart" initiatives		
Bottom-up: Stakeholders / community, instead of city government, initiate "smart" projects. Grassroot efforts surface ideas & technologies that find application.	*Middle-out: City government provides some definition of specific issues or problems, facilitates opportunities for ideas & technology to respond openly.*	*Top-down: City government initiates "smart" projects, setting goals and specifying technologies and framework.*
Unhackathon / Summer of Smart, San Francisco	Citizens Connect, Boston; Climate Street, Amsterdam; Living Innovation Zone / CleanTech, San Francisco; Jurong Lake District, Singapore; Stockholm Royal Seaport	COR, Rio de Janeiro; Traffic Management, Singapore

Table 5 - Examples of "Bottom-up", "Middle-out" and "Top-down" approaches to "smart" initiatives

On one end of the spectrum, Rio's COR was a "top-down" initiative. As described by Singer (2012), the 2010 floods and landslides triggered the city's decision to implement COR. Singer described Mayor Edward Paes' actions of declaring an adhoc emergency, and how after the event, he "decided that Rio could do better". Mayor Paes initiated the idea for COR with IBM and "wanted his new operations center to open as soon as possible". The city put in concerted efforts to implement COR and according to The Daily Beast (2011), was "built from scratch in four months with only four engineers and was ready four days ahead of schedule".

On the other end of the spectrum, San Francisco takes a largely "bottom-up" to "middle-out" approach. Nath (2012) describes the facilitative but minimal role of government "to create a space for the entrepreneurs, the artists, the innovators to explore, to use their creativity and intellect to push things forward". This is reflected in the city's approach for an open data platform, encouraging hackathons, and openness to "disruptive" new ideas and models that challenge existing regulations. Nath describes city permits on the use of physical urban space as a "new API for making change in (our) urban environments", and welcomes projects that rethink unused city space and physical assets.

Many of Singapore's "smart" initiatives range from "middle-out" to "top-down", led by city agencies. In the inter-agency implementation of the Jurong Lake District project, according to the EDB officer interviewed, the various agencies involved take the lead in the conceptualization and formulation of "problem statements". For example, IDA would focus on issues relating to the provision of backbone ICTs infrastructure such as long range, short range, fiber and wireless networks, while LTA would consider the possibility of new solutions such as urban sensors which relay real-time traffic information to commuters, or apps which show real-time information on how crowded buses are. After the "problem statements" and ideas are conceptualized by city agencies, essentially through a "top-down" approach, these are then opened to technology providers to develop innovative solutions. Here, the process becomes more "middle-out" in nature, where agencies' openness and flexibility allows technology providers to propose a wide range of solutions.

In Amsterdam's case, according to the city official interviewed, the city takes a "collaborative" more than a "top down" approach. Amsterdam Smart City has more than 70 partners, which provide the city a wide pool of technology providers and ideas in implementing "smart" initiatives to help achieve various city environmental, economic and livability objectives. The approach, technology and composition of each project team is thus unique, and one of AIM's key role is to help different partners pursue a common and strategic objective. In particular, for the Utrechtstraat "Climate Street" initiative which can be described as "middle-out", the project was initiated by the City of Amsterdam, Amsterdam Smart city and the Union of Entrepreneurs of Utretchstraat, engaging the Club van 30 (a sustainability business consultant) and 40 local entrepreneurs to implement testbedding initiatives (Amsterdam Smart City 2013).

For Boston, the genesis of "smart" initiatives depends on the nature of the project. According to Osgood (2013), its "Community PlanIT" initiative arose from the work of faculty from Emerson College and was adopted by the city. On the other hand, its "Citizens Connect" initiative stemmed from MONUM, who subsequently engaged a local developer to develop the app. Boston's "Street Bump" initiative emerged from an idea from the Chief of Staff and a researcher. While there is emphasis on citizen-empowerment tools, many of Boston's initiatives are "middle-out" in nature, chiefly driven by its government as they relate specifically to government functions, while at the same time, adopting a flexible and open approach to technology and implementation methods.

The majority of "smart" initiatives examined involve city governments, although their roles vary. The "top-down" projects (e.g. Rio's COR, Singapore's traffic management) are characterized by strong government involvement in initiation and conceptualization, and closed partnerships with limited numbers of technology providers, using specific technologies. Many of the other cities' "smart" initiatives are predominantly "middle-out", involving city agencies taking the lead in framing the issues, such as focus areas to address (e.g. using apps to improve city service delivery), or a specific location, neighborhood or district to implement test-bedding

initiatives. This appears to be characteristic of many of the cities examined, for example, Stockholm Royal Seaport, Singapore's Jurong Lake District, Amsterdam's "Climate Street", San Francisco's "CleanTech / Living Innovation Zone", etc.; with direct relevance to city planning. Compared to the "top-down" approach, the "middle-out" model in a location-based test-bedding initiative appears to adopt a wider base of partners and a degree of openness toward possible "smart" solutions. This could be linked to the complexity and variety of solutions, for example, ranging from energy to telecommunications to waste management, as seen in the case of Stockholm Royal Seaport. In addition, through the "middle-out" approach, a possibility is that city governments see the opportunity to seek buy-in from the larger community on the issues framed. This could also involve the dimension of city governments knowing some aspects of and having some expertise on the issues, but acknowledging that potential solutions arise outside their own capabilities. Another possibility is that city governments, aware of the longer time frame in implementing, testing and assessing results of initiatives for new physical neighborhoods or districts, see the need to remain open to a wider range of strategies and possibilities, and to remain flexible to future changes due to changes in technology. The question remains whether such an approach will outlast the "top-down" approach, where current and specific technology, while addressing issues of the day, may possibly lose effectiveness amidst fast-changing conditions.

Avoiding Lock-In

For some of the cities examined, taking the "middle-out" or a "bottom-up" approach is related to what these cities have set out to avoid - technological "lock-in" in the form of restricted proprietary data formats or inflexible partnerships with technology providers. These cities see such avoidance as part of a long-term sustainable partnership framework.

For Boston, Osgood (2013) highlights that MONUM "has a bias towards open source approach to share ideas"; this is corroborated by Lane (2013), who states that city's "philosophy is to have open data" such as maps and business information. In terms of partnerships, there is no single technology provider as the city "aims to get something of value out of (each) partnership", for example, the city partnered ESRI for the "School Choice" initiative, SAP for business intelligence initiatives, and IBM for the "Smarter City" transportation analysis.

Similarly, the "open platform" nature of Amsterdam Smart City relies not on any single technology provider, but matches specific city needs with the resources and technological capabilities of its partners.

As part of Stockholm Royal Seaport's test-bedding of innovative sustainability solutions, the city adopts "an open and generic ICT infrastructure" which they believe is beneficial for the long-term and critical for success:

> *"Today's ICT solutions are industry specific and consist of closed, proprietary systems, resulting in unnecessary costs and resource consumption, with limited potential for innovation and new services. A generic solution will be able to fulfill the needs of many business segments, such as transportation, health, energy, and media... we argue that a well-planned generic ICT infrastructure holds the potential of facilitating the coordination and collaboration between actors of different sectors, as well as the people of Stockholm Royal Seaport, required to live up to the ambitious sustainability goals. We further state that by enabling this platform for multi-level collaboration, we facilitate a new range of innovation opportunities with the focus on sustainable solutions and growth."* - Stockholm Royal Seaport (2013)

Taking this approach, Stockholm intends to avoid technology lock-in and ensure the long-term sustainability of their "smart" efforts.

Overcoming Challenges in Collaboration

From the cities examined, whilst cultivating a strong partnership has been highlighted as an important dimension for the successful initiation and implementation of "smart" initiatives, one commonality surfaced is the need to overcome friction between different partners in collaboration.

Rooney (2012), in his analysis on San Francisco's efforts, highlighted the need for closer collaboration between the community and city government. For example, he cited how hackathons were held with citizens coming together to solve problems using data and technology. From one hackathon, a "broken-bus" app was developed to track buses which broke down. However, as an illustration of the gap between the community and city government, it took nine months after the hackathon for the app to be officially adopted and implemented by the city. Rooney reports that organizations like Code for America are aware of this gap and suggests that more is needed for these bottom-up efforts to "make a real impact on the lives of city dwellers".

In the context of overcoming challenges whereby different agencies enter the collaboration with different requirements, Tay (2013a) describes the "natural process" involved for agencies to "understand how to work together and to be of value"; as agencies commit resources to the project, it is important that they are aware of "the larger goals". The EDB official interviewed also echoed this, highlighting the need to overcome differences in agencies' points of views through a common strategic focus. For example, the official cited a specific structural challenge in the implementation of a collaborative "smart" initiative, in the difference in the "level of ambition" between agencies. Here, an economic development agency could be interested in the implementation of "smart" initiatives that are innovative, cutting edge and potentially "disruptive", whereas a line agency could be more concerned with "tried and tested low-cost solutions" for its

operational needs. Hence according to the official, such collaborative partnerships often involve finding the "middle ground".

To address this similar issue of closing the gap between technology-driven agencies and operational line agencies, the approach taken by Boston's MONUM is for MONUM to "broker the partnerships with the thought leaders within these agencies" (Osgood 2013) to establish buy-in, while ensuring that "smart" initiatives are practical and can be scaled up in the future.

Another challenge in collaboration is technical in nature. Tratz-Ryan (2011), in her analysis of Rio de Janeiro's COR, observed how the integration of different agencies under one roof had not reached "the full capability" and will take time to do so:

> *"After talking to the people and getting an understanding how the feeds of data and information from different database and simulation schemes such as weather, topological changes and traffic are being analyzed, it was clear that the process of aligning and standardizing syntax and information logic across the agencies will not happen overnight.. Even though the data cannot be integrated through all the systems, as every system takes time to identify a common syntax in all of the information, the action items that are triggered through the information displayed on the large monitor screens are. So the 'man pool' in the center provides the human interface to all the different organizations."*

This example hence serves as an illustration on the challenges of data and systems interoperability. Interestingly, while the specific COR functions such as weather prediction and traffic management can be likened to be individual "smart" machines which harness machine automation and intelligence, however, as an integrated whole, COR relies on the human element to unite the different functions by applying "appropriate standard operating procedures" to respond to different scenarios.

From the above examples, whether the collaboration is between governments and the community, between city agencies and departments and / or technology providers, the human element that finds the "middle ground", "brokers partnerships" and overcoming lack of interoperability, is still an important factor that contributes to successful collaboration.

Theory C - Cities that Learn, Relearn and Adapt

Assumptions: The "smart city" learns, relearns and adapts itself, through learning networks, as well as using metrics, monitoring and feedback processes.

The cities examined display evidence of continual learning and the use of metrics and feedback loops.

Continual Learning

Most of the cities examined learn from other cities, through conferences, visits and other knowledge networks, and also share their own experiences, as shown in

Examples of cities and their avenues for learning			
Providing detailed documentation and results of "smart" initiatives	*Hosting Learning Visits for local, regional and international groups*	*Part of a network of cities actively exchanging ideas & solutions, using common platforms*	*Sharing at local and international conferences*
Amsterdam Smart City "Smart Stories" publication and knowledge website	Stockholm "Professional Study Visits"; Amsterdam Smart City hosted visits; Singapore IDA hosted visits	Boston G7 network; Boston open data (Socrata) platform; Stockholm C40 Network	San Francisco Meeting of the Minds conference; Amsterdam Smart City Event conference; Singapore World Cities Summit

Table 6 - Examples of cities and their avenues for learning

For example, Boston's MONUM works closely with a core network of cities including New York City, Chicago, San Francisco, Philadelphia, Seattle, Colorado Springs, etc. to freely share and readily adapt ideas. Boston is also part of the informal "G7" network of U.S. cities – i.e. Boston, Chicago, Los Angeles, New York City, Philadelphia, San Francisco and Seattle – where the Chief Information Officers (CIOs) or equivalent exchange ideas. For example, the cities are collaborating on an open data platform using Socrata, standardizing their data and making it easier to share applications (Towns 2012). According to Osgood (2012), during the 2013 flu epidemic in Boston, the code for a public health app from Chicago was shared on Github and within 24 hours, an app for Boston was released. Another illustration is Code for America's "Adopt a Hydrant" initiative, which is now shared and used amongst many cities, together with their variants. In general, Osgood cited that there is strong interest for cities to learn from one another, and highlights greater potential to share knowledge and experience on the "methodology of evaluation, so that municipalities can know how to assess their own efforts". In addition, Boston hosts learning visits from other cities, for example, a visit from the New York Fire Department to learn about computerized dispatch functions, as well as international groups from Sweden, Australia, etc. The city also shares its experiences and learns from other cities at conferences, for example, GIS applications at the ESRI user conference.

For San Francisco, apart from the collaborative networks, the city agencies participate actively in international conferences, including those hosted locally. For example, at the 2012 "Meeting of the Minds" conference, where cities "identify tested and untested solutions that can help us build connected and sustainable cities and regions, and to share those solutions with each other" (Meeting of the Minds

2012), San Francisco shared its experiences on its strategies to spur innovation, some of its "smart" initiatives such as the "Innovation Zone", and its future technological roadmap. At the 2012 California France Forum on Energy Efficiency Technologies (CaFFEET) which aims to extend collaboration between U.S. and French Cities, SF Environment also shared its experiences on "smart" initiatives relating to energy use and policies.

Amsterdam shares its experience on "smart" initiatives readily at events and conferences. For example, the city has been hosting for the last three years the "Smart City Event", a two-day conference involving city and corporate leaders who discuss the implementation, benefits and challenges of "smart" initiatives. The 2012 event saw more than 350 participants (Smart City Event 2013). In addition, according to the city official interviewed, Amsterdam also hosts many requests from other cities, including those from Japan, Denmark, Spain, etc., who send delegations to visit and learn about their initiatives. The Amsterdam Smart City website also contains links to other "smart city"-related content such as city networks, non-profit institutions, research findings from institutions, as well as documents and reports of its initiatives. Its "Smart Stories" report features sixteen of the city's projects, detailing the objectives, research involved, key statistics, lessons learned, and next steps (Amsterdam Smart City 2011). The freely available content thus allow other cities to learn from Amsterdam's efforts and experiences.

Stockholm participates actively in international conferences to share its experience on "smart" initiatives. For example, for the Stockholm Royal Seaport project alone, the project team made presentations to other cities as part of the Clinton Climate Initiative and C40 network, in 2012 they hosted and presented to about 5 external delegations per week all year round, and also visit a number of cities around the world (Claeson 2012). The city also hosts delegations under the "Professional Study Visits" program "to strengthen the network with other cities and increase the possibilities of sharing experience and learning from one another". Under the program, customized study visits are arranged to learn from the city's experience in the city governance, green efforts, application of ICT, urban development and renewal, mobility and sustainable travelling, waste management, water management, etc. For example, this could be a 1 ½-hour tour of Stockholm Royal Seaport or an 1-hour visit to Stokab.

Singapore shares its experience on its "smart" initiatives with other cities through hosted visits and international conferences. For example, the biennial World Cities Summit (WCS) event is a high-profile conference organized by Singapore, serving as a "global platform for government leaders and industry experts to address liveable and sustainable city challenges, share innovative urban projects and forge partnerships" (WCS 2012). The event includes plenary sessions with topics on "smart", "eco", "biodiverse", "resilient" cities, a Mayors Forum, and the Lee Kuan Yew World City Prize that "honors outstanding achievements and contributions to the creation of liveable, vibrant and sustainable urban communities around the world" and shares best practices. In addition, a concurrent trade show provides the

platforms for cities and technology providers to showcase and share their "smart" initiatives and technology solutions. The event had a very wide reach, with representatives from more than 212 cities attending the 2012 WCS, including more than 90 mayors and 3,200 delegates and trade visitors (CLC 2012).

The examples show that many of the cities participate actively in conferences, networks and hosting visits, both to share their experiences in implementing "smart" initiatives, but also to continually learn from others. The sharing of information or even code for apps in Boston's case, demonstrates that knowledge can be transferred relatively easily and refined for the local context. The example of Amsterdam Smart City stands out in its efforts to document and publish the details of its experience, made easily available through their website. Their efforts have also contributed to a recognizable "brand" as a leading European "smart" city with a high level of experience and expertise. A secondary effect, as seen in the case of Singapore's WCS trade show, is that cities and technology providers are able to showcase their efforts. Again, this has the potential to burnish the brand image of the cities as "thought-leading" and inspiring confidence, and to possibly expand business opportunities for the technology providers.

Use of Metrics

Although this research was not able to obtain specific data on the detailed metrics and performance of the "smart" initiatives, it was evident that most of the cities are aware of the use of metrics and criteria for assessment to evaluate the success of their initiatives (see Table 7). Many city officials pointed out that metrics are dependent on and specific to the nature of each initiative, and these metrics are also important in the decision-making process to justify the prototype launch and subsequent up-scaling and implementation of the projects.

Examples of cities' use of metrics		
Aware of the use of metrics in their "smart" initiatives, some aspects not implemented yet (e.g. data collection)	*Uses metrics to assess the effectiveness of their "smart" initiatives.*	*Evaluates organization and processes, in addition to using metrics for their "smart" initiatives.*
San Francisco "SF Park"	Amsterdam Smart City	Boston's "Citizens Connect" action research; Stockholm Royal Seaport new sustainability unit

Table 7 - Examples of cities' use of metrics

For Amsterdam, KPIs are set for each project, for example, amount of CO2e reduction, number of jobs created, number of citizens involved, etc. Being a central node in its partnerships, AIM tracks each project, the partners involved, as well as the investments made.

In Boston's case, evaluation is made on two dimensions. First, metrics are used to assess the success of each project. For example, for the "Citizens Connect" initiative, this involved assessing how the initiative resulted in changes in behavior, how many members of the public used the app, etc. Metrics for a web application could be based on its web statistics, e.g. number of downloads, number of visits, etc. The evaluation for "Citizens Connect" was made by an independent research team from Harvard University, and MONUM is keen to adopt an "action research project approach", whereby a researcher is "embedded" with each initiative to follow and assess the project closely. The second dimension involves the prototyping process for each initiative, for example, how effective the project team was in sourcing ideas, getting support from partners and the community, and eventually up-scaling the project as part of implementation.

For some of the cities examined, city officials highlight that some of the "smart" initiatives are still in the initial or prototype stages and the metrics are being developed, or the projects are difficult to evaluate at this point in time without adequate data.

For example, for San Francisco, Miller (2013) acknowledged that for some "smart" initiatives, "we haven't developed a definitive process for evaluation. However, data collection and analysis will be critical to evaluating each project's success... the City will undergo an evaluation process with the recently launched SFpark, but doesn't have data yet."

For Stockholm, "smart" technology is planned for monitoring at the district, block and apartment level as part of the Royal Seaport project. According to Claeson (2013), the results are yet to be seen but the city is "hopeful... to learn from the first stages of the project to implement improvements in the coming stages". To do this, the city has set up a new sustainability unit, and is "building up assessment models and follow up strategies" where measurement will be taken for "at least five years after each building (has) been built". These demonstrate the instrumentation and processes that the city has integrated as part of the project implementation.

Boston and Stockholm stand out as examples where evaluation extends beyond the use of metrics in their "smart" initiatives. Boston's "action research project approach" has the potential to assess the processes undertaken by the implementing agency, MONUM, its interactions with other city agencies and decision makers, and thus can inform the agency on ways to improve the implementation processes. This example also highlights how cities can collaborate with research institutions not only in the technology aspects of their "smart" initiatives, but also in terms of its processes.

For Stockholm, the setting up of a new sustainability unit in tandem with its implementation of its "smart" initiatives reflects far-sighted and serious effort to assess its own efforts, beyond the existing organizational framework of its

implementing agencies. It is also possible that such a new department provides independent assessment and review as part of the city's feedback mechanism, given that the new department can be set up fall outside existing funding and decision-making structures and hierarchies.

Use of Feedback Loops

The use of feedback loops from the "smart" initiatives is not evident in all the cities, although some cities are aware of the potential opportunities and benefits in linking findings from city management operations to longer-term planning.

Examples of cities' use of feedback loops		
Uses feedback loops within their "smart" initiatives to fine-tune the initiative and inform internal processes	*Uses feedback loops within their "smart" initiatives to fine-tune the initiative and inform internal and external processes and policies, including those of other departments and agencies*	*Uses feedback loops, extended to provide critical review and willingness to abandon technology and set up of "smart" initiatives*
San Francisco City Departments and "Charge Point"	Amsterdam Smart City decentralized energy production (review of policies); Singapore LTA traffic management (long-term landuse-transportation planning)	Stockholm Royal Seaport

Table 8 - Examples of cities' use of feedback loops

For San Francisco, Miller (2013) highlights that the city's "long-term goal is to integrate each individual system into a single network", where there "smart" initiatives can provide feedback to longer-term or upstream city processes. It is seen that the current involvement of many city departments in existing initiatives – e.g. Mayor's office (Open Data SF), the Public Utility Commission (LED streetlights), the San Francisco Municipal Transportation Association (Next Bus app), the Planning Department (mapping POPOS), etc. – presents a good starting point to build this effort. Nutter (2012) describes the collection of data from the EV charging stations under the "Charge Point" network to "help ... determine strategies for future implementation", for example, additional locations for new EV charging stations, and "how to make (San Francisco) a more EV-ready city".

In Singapore's case, LTA's traffic prediction provides feedback to its other planning and operational functions. According to the LTA official interviewed, in the immediate sense, information is used for traffic management, for example, relaying information on traffic delays and incidents for road users' decision-making. For the medium term, the information is used for operational improvements such as changes to the road layout, markings, and road or junction geometry and signaling. For the longer-term, the information is used for transportation planning purposes,

for example, using traffic volumes for macro and micro-scale traffic modeling, as well as for integrated transportation and land use planning. For IDA, feedback mechanisms include the documentation and sharing of knowledge and learning points arising from project reports and post-implementation reviews.

In Amsterdam's case, feedback loops are used at multiple levels. On one level, the project KPIs and metrics are used to evaluate each "smart" initiative's products or services. Feedback on each project, which often starts as a smaller-scale pilot, is shared between parties involved, for common learning and more importantly, to assess whether the initiative can be upscaled. On another level, issues uncovered from the "smart" initiatives are surfaced to the city. For example, in a pilot project on local decentralized energy production in residential buildings through the use of solar panels, the community realized found that under the existing tax regime and energy regulations, they were not able to exchange energy produced. Through the project, the community provided feedback to the city government and advocated that decentralized domestically produced energy should not be subject to tax; according to the city official interviewed, if adopted, policies like this may cascade upwards to the national government level.

For Stockholm's Royal Seaport, Claeson (2013) highlights that the nature of the development project, with its integrated research and development, constantly involves city agencies and its partners in "an iterative process with feedback (that) directly influences" the work. On one level, as Swedish ICT points out, the evaluation of prototype ICT sustainability solutions, using "usability as well as sustainability measures", "seeks to compare the outcome of its use to intentions formulated at the concept development phase" (Bylund et al 2011:29). This allows the initiatives to be upscaled and / or commercialized. On another level, the same report charts out the approach for the longer term:

> *"Evaluation of the effect of deployed ICT is an integral part of ICT design and development. But the development plans for the Stockholm Royal Seaport span a period of nearly two decades, and the estimated life-time of the planned buildings are far greater than that. During that long period, people's habits as well as engagement will evolve, the technological infrastructure will be replaced... These changes are likely to affect the use and effects of the planned ICT solutions. Some technologies, once effective and appreciated, may become out of date after only a few years... Others may influence the habits and behavior in unexpected ways... Thus, the effect and use of deployed ICT, in particular technology with the aim of affecting behavior of people, will have to be followed up continuously over time. A number of steps for facing the evolution of habits, technology, and environment should be planned for... (including) feedback mechanism, distribution of information, re-design and modification, and the discarding (of) outdated technologies."* (Bylund et al 2011:31)

Stockholm's open and flexible approach encapsulates the use of bi-directional feedback mechanisms, i.e. how ICTs can influence behavior and plans, and how evolving behavior and plans can influence ICTs. In comparison with the other cities, Stockholm's approach is also noteworthy in its boldness to potentially redesign, modify, and even abandon irrelevant technology as a result of its feedback mechanism. Under this concept, even the "smart" initiative that was originally implemented could see its technology and core set up discarded in response to future changes.

The example of Stockholm and other cities, e.g. the incorporation of short, medium and long-term feedback loops in Singapore's traffic management and the review of energy policies in Amsterdam, also point to broader opportunities that may be embraced by cities as they implement their "smart" initiatives. In particular, the incorporation of feedback mechanisms, when extended beyond the purview and processes of the implementing agency, could yield wider benefits especially for the longer-term. For example, in the case of Rio de Janeiro, pre-emptive action could be taken for areas identified through the system's feedback mechanism, i.e. hotspots heavily prone to flooding and landslides as determined through predicted and actual events. Hence, the results of the city's short-term operations could inform longer-term actions and plans, such as the possible implementation of physical infrastructure (e.g. retaining structures, flood diversion systems, etc.) and adjustments to existing policies (e.g. land use and settlement policies around high-risk zones).

Whilst Stockholm's concept is unproven at this point in time, it presents an extreme scenario in the conceptualization of a city's "smart" initiative and processes and raises other questions. Given investments made into cities' "smart" systems, are cities willing to take such drastic actions in practice, or will they be more likely to make incremental changes to their technologies and systems? Does a city's investment vis-à-vis its perceptions of the returns on investment (ROI) of its "smart" efforts influence the make-up of its initiatives, its implementation processes, and its willingness to change? How can a city incorporate feedback loops within its strategies, for example, through bootstrapping, to incrementally build up its systems and capabilities? Will a view towards reaping wider benefits, either through feedback mechanism or ripple effects, influence cities' conceptualization and implementation of "smart" initiatives?

Theory D - Investing for the future

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

The cities examined embarked on their "smart" initiatives, through the investment of resources, with objectives to reap greater benefits for the cities. For some of the

cities, the agencies involved took a wider, long-term view on the benefits, which may be less tangible or may not be directly monetized.

Capital Costs and Returns-on-Investment

From the cities examined, it appears that whilst some cities may be generally aware of a returns-on-investment (ROI) model, in particular through cost-benefit analysis, however, there is no evidence that all the cities adopt a strict ROI business perspective in the conceptualization and implementation of their "smart" initiatives. In addition, the cities have different models of funding related to the scales and types of projects, and the implementing agency involved.

Examples of city agencies and their funding models for "smart" initiatives			
City agency does not provide funding, but provides existing physical assets and / or manpower resources to mobilize & organize collaborative efforts between city departments and / or technology providers	*City agency does not provide funding, but seeks and obtains funding from other sources (e.g. higher tier government, foundations) to facilitate "smart" initiative*	*City agency provides seed or partial funding for small-scale prototype, in partnership with technology providers*	*City agency provides full capital funding for "smart" initiative*
Amsterdam AIM; Singapore IDA	Boston MONUM; San Francisco SF Park	Singapore EDB "Living Lab" fund	COR, Rio de Janeiro

Table 9 - Examples of city agencies and their funding models for "smart" initiatives

Examples of "smart" initiatives: Scales of investment		
Low or almost no level of capital investment involved: e.g. through facilitating collaborations. Initiatives are generally small to medium in scale.	*Medium level of investment involved, e.g. city or collaborative funding for test-bedding, implementation of relatively small-scale initiatives. Initiatives are generally small to medium in scale.*	*High level of investment involved: e.g. city-wide turnkey integrated ICT system, district-wide infrastructure. Initiatives are generally medium to large in scale.*
Amsterdam AIM; Boston MONUM	JLD, Singapore	Stokab, Stockholm; COR, Rio de Janeiro

Table 10 - Examples of types of smart initiatives in relation to cities' scales of investment

For Singapore's "Traffic Prediction Tool" developed in collaboration with IBM, the LTA officer interviewed highlighted that the initiative is currently under trial and as such, the overall benefits are difficult to assess at this point in time for this specific project. Notwithstanding this, a cost-benefit analysis is typically undertaken to help justify budget expenditures for "smart" initiatives. In the case of traffic management, for instance, this would take into consideration negative externalities such as the economic costs resulting from traffic delays. For EDB, its S$100 million

(~US$ 80 million) "Living Lab" fund acts as a seed fund to "facilitate private and public sector tie-ups to test-bed new clean energy, urban mobility, IT and public safety systems" (Teh 2010). According to the EDB officer interviewed, while EDB is aware of the need to evaluate projects based on economic indicators that reflect ROI (e.g. economic value-add, number of jobs created, business spending, etc.), however, many of the test-bed projects are small in scale and hence "need not be assessed on such criteria until (there are) larger rollouts". Thus, the capital investment for prototypical "smart" initiatives plays a more flexible "seeding" role.

While some cities make capital investments in their "smart" initiatives, there are also cities that do have dedicated or additional budgets for their "smart" initiatives. Instead, their projects are funded through partnerships with the private sector, other levels of government or through mobilizing the manpower resources of city departments.

Even for Singapore, depending on the nature of the project, agencies like IDA may play a more facilitative role – i.e. investing manpower resources rather than capital resources - to organize or mobilize new partnerships between agencies, technology providers and the community (Tay 2013a).

Similarly, Amsterdam's AIM invests its manpower resources and organizing capabilities to create the platforms for collaboration; according to the city official interviewed, AIM does not involve itself in the funding or ownership of "smart" initiatives.

In Boston's case, MONUM started with 2 staff and while it has since added a few more, it still remains a small office that implements its "smart" prototypes with funding from non-profit foundations (e.g. MacArthur Foundation, Bloomberg Foundation) and the State. To implement initiatives, MONUM has had to "borrow" the manpower resources of the city's line agencies (Osgood 2013), which also provide capital funding for the initiatives. However, Osgood highlights that this is not necessary a disadvantage, as such an arrangement is "important for projects to upscale in the future", as line agencies take over full ownership of the initiatives.

For San Francisco, the city has no dedicated budget for its "smart" initiatives, but takes on these projects through its various agencies and seeks funding from other sources. For example, 80% of the funding for the SFpark project is from federal funding through the Department of Transportation's Urban Partnership Program, and the pilot testing of the project uses city-owned metered parking spaces and garages. In view of the lack of dedicated capital budget, Miller (2013) highlighted the importance of such partnerships in launching and testing the city's initiatives.

The diversity in funding models reflects the different approaches taken by the various cities, which are heavily influenced by the role and nature of the city agencies. Whilst this study was unable to obtain data on actual expenditure and investments for the cities' initiatives and the projected benefits, it can be seen that

not all "smart" initiatives require heavy investments from city governments, but instead would depend on the nature of partnership with technology providers and businesses as co-investors. This is particularly so when there is an element of test-bedding and prototyping, where technology providers and businesses may upscale and commercialize their "smart" solutions drawing from their experience in the collaboration.

Another observation, relating to cities' use of metrics to assess their "smart" efforts, is that since most "smart" initiatives requiring large capital investments would typically need city agencies to make justifications for the expenditure from their budgets, further investigation could examine the planning, implementation and decision-making processes that cities undertake with their technology providers in embarking on these projects. In addition, as this study was not able to obtain data on the details of the cities' ROI models and their levels of investment, more investigation could also analyze the interactions between city objectives, policy-making and the perception of benefits arising from the "smart" initiatives. For example, this could compare cities' attitudes and objectives towards reducing negative impacts due to traffic congestion (e.g. minimizing economic costs, reducing CO2e) against their willingness-to-pay for different "smart" solutions requiring varying levels of investment and resources. Further investigations could also evaluate the objectives behind, and the considerations that cities take, regarding when and what specific models of technology are adopted. For example, a city may choose to be an early adopter of a specific emerging technology developed by its local firms as a form of economic support. Alternatively, a city may choose a specific turnkey technology and its technology provider as part of its marketing efforts to boost its own image, or to gain access to knowledge or future collaborations in other sectors.

Directly Monetizing "Smart" Initiatives

There is also no evidence that the cities examined have explicit intention to directly monetize and gain from their "smart" initiatives, whether it is the sale of data or information collated as part of the initiative, or the actual product such as a web or mobile app. For example, in terms of the sale of data, which may seem to be an obvious source of revenue, many of the cities examined (i.e. Boston, San Francisco, Amsterdam, Stockholm, Singapore) have instead taken an open data approach. These cities appear to be aware of the longer-term benefits of an open approach and the free use of data, subject to the city's terms and conditions, to spur innovation, improve the delivery of city services and enhance community engagement.

In the case of Singapore's LTA traffic prediction and management system, according to the LTA official interviewed, the data are owned by LTA as they are generated as part of LTA's projects. Some data are made available to the public openly (e.g. real-time traffic incidents) while some data (e.g. traffic predictions) are restricted to be shared with partners such as research institutions at no cost. Tay (2013a)

highlights that the open data approach encourages technology providers to use the data in collaboration with city agencies, for example, to develop apps to enhance the delivery of city services.

For Boston, according to Osgood (2012), MONUM "has a bias towards an open source approach to share ideas". Acknowledging that some technology providers may have commercial interest in pursuing the "smart" initiatives, in this case, given the commercial nature, the city will invest less in such projects. Thus, the city's focus is more on the effective delivery of services rather than the monetizing of its "smart" initiatives.

Longer-Term Wider Benefits

Instead of direct monetized gains, the cities examined tend to take a longer-term and wider perspective on the larger economic, environmental and social benefits that may arise from their "smart" initiatives. The cities are also aware that new technologies and innovations that arise from their initiatives may be subsequently commercialized by the private sector.

For Amsterdam, AIM plays a central facilitator role in the city's "smart" initiatives, and provides manpower resources and time in coordinating the projects. According to the city official interviewed, AIM's underlying interest is to spur innovation and economic development. Hence, the typical model is for project partners and technology providers to make the investment of resources as business decisions, i.e. whether to embark on a pilot project and if successful, whether to scale up the investments. Thus, if an innovative product arises from the "smart" initiative, the companies involved will own the product and stand to gain from commercializing it, while the city and communities benefit from other dimensions.

For Stockholm, Stokab, a company owned by the city of Stockholm via Stadshus AB a holding company, has seen operating profits since 2008; however, the broader impacts of Stokab's efforts have been in generating "significant positive benefits to the local economy" through enhancing the city's attractiveness as a technology hub with excellent infrastructure, high administrative efficiency, and as a driver for innovation (Felten 2012). Stockholm's model of providing dark fiber network as a public city infrastructure thus lays the foundation for the city's pursuit of its wider economic, social and environmental sustainability goals. According to Broberg (Smart + Connected Communities Institute, 2012b:49), the network contributed to the city's knowledge economy and buffered the city from the economic crisis, supports social programs such as helping homeless citizens find jobs, as well as environmental initiatives in traffic management, planning, and reducing energy consumption. The test-bedding of initiatives as part of the Royal Seaport project, with partners such as Vinnova, the Swedish Governmental Agency for Innovation Systems, also takes a longer-term approach to develop innovative sustainability solutions that can be commercialized.

In Singapore's case, EDB and IDA see "smart" initiatives as instruments for primarily addressing national needs and secondarily, acting as catalysts for the growth of its local urban solutions sector. According to the EDB official interviewed, the urban solutions sector, which encompass "smart" initiatives, is seen as a promising economic sector due to the global "mega trend in urbanization". Hence, the test-bedding and development of initiatives which meet Singapore's needs to "enhance livability and reduce resource consumption" can be subsequently "exported" and applied to other cities, as seen in the case of Singapore's water technologies industry. The development of "smart" initiatives, in partnership with technology providers, also boosts the local capabilities and knowledge of city agencies and local companies through technology transfers. In addition, "smart" initiatives help to boost Singapore's image as a "thought leader" in urban solutions and planning, an intangible but beneficial value.

According to the C40 Blog (2012), Rio de Janeiro's investment in COR stemmed partly from its assessment of "risk and challenges", in particular, the high-profile mega-events which the city would be hosting. These events include the Rio+20 United Nations Conference on Sustainable Development held in Jun 2012, as well as the upcoming 2014 FIFA World Cup and the 2016 Summer Olympics. Hamm (2012) observed that:

> *"Rio's Maracana stadium, the venue for the World Cup final and the opening and closing Olympics ceremonies, is located in one of the severe flood zones. In Rio, extreme weather and society co-exist. Nothing will alter that. The only thing that can change is the way the city deals with the situation."*

Hence, he sees the city's initiative as "investing for the long term", a way to mitigate the inevitable risks arising from severe weather and flooding.

Synthesis: Different Approaches

The findings from the cities examined reflect the different approaches taken between cities. Whilst even for some cities, the approaches between different agencies and projects vary; there are general observations that characterize each city and which can be summarized here. Understanding the cities' different contexts, approaches and the nature of their initiatives will help to draw lessons.

Different Approaches: General Characteristics of Cities

Rio de Janeiro's COR is characterized by a "top-down" approach of implementation, involving a closed partnership with IBM. The system has been specifically designed to address the core focus areas identified by the city, i.e. weather prediction, emergency response, traffic management, etc., combined with reorganization of its

city departments and functions. There may be opportunities for the city, having "bought" into the current system, to explore innovation in new combinations of technologies and applications (e.g. expanding crowdsourcing methods to provide citizen feedback and inputs), as well as consider multiple-loop feedback linking to other city processes (e.g. land use and infrastructure planning, etc.).

Similarly, some of Singapore's "smart" initiatives are characterized by a "top-down" approach with a closed partnership, e.g. traffic management, as well as large capital budgets for investment. However, unlike a full new system in Rio de Janeiro's COR, this was based on an incremental approach introducing new functions within an existing organization and framework. Some initiatives take a more "middle-out" approach, e.g. Jurong Lake District, with the agencies involved (e.g. EDB, IDA) playing a supportive role for the development of new prototype solutions by framing problem statements instead of prescribing the specific application of a technology. Given the test-bedding, there may be more opportunities for increased collaboration with research institutions, in particular, to assess the effectiveness of prototypes, as well as the processes of innovation and implementation. Thus, multiple feedback loops at different scales could also be incorporated, for example, to treat the planning and implementation of the entire sustainability district as an integrated planning "prototype", instead of only individual technology projects.

In general, Boston takes a "middle-out" to "bottom-up" approach to its "smart" initiatives. With relatively small agencies like MONUM and DoIT driving innovation, their projects are also typically smaller in scale and capital investments, relying on a variety of partnerships including other city departments and technology providers, and typically taking an incremental approach to change. For example, many of DoIT's initiatives (e.g. data integration) involve their own staff efforts more than engaging external technology providers to introduce "turnkey" projects. Boston's wide range of initiatives reflect the nimbleness in which small agencies can capitalize on good ideas, match them to specific city needs, and produce innovative solutions. The organization of MONUM, an agency outside the hierarchical structure of other city agencies / departments while maintaining strong lateral links, also allows the city to think and act outside of the box in innovation. In line with the city's efforts to create feedback loops (e.g. through action research) that reflect the city's interest in creating sustainable processes of innovation, there may be opportunities to explore how their established approach and know-how of idea generation, innovation and implementation (e.g. partnership with technology providers), as well as citizen engagement (e.g. "Community PlanIT", "Citizens Connect", etc.), may be scaled up to cater to possible large-scale "smart" initiatives such as city-wide infrastructure (e.g. traffic management, smart grids, waste management, etc.).

In several ways, San Francisco appears similar to Boston, with its "middle-out" to "bottom-up" approach, small agencies driving innovation and engaging in typically small-scale initiatives. The city's "bottom-up" entrepreneurial innovation approach is especially appropriate in its culture and setting of having numerous technology

entrepreneurs, tapping on their expertise rather than relying on a "top-down" process, to stimulate innovation, foster economic growth and enhance the delivery of city services. Like Boston, its challenges and opportunities may involve up-scaling its innovation processes to support possible large-scale "smart" initiatives that in line with the city's sustainability objectives (e.g. traffic management).

Amsterdam's "smart" initiatives are wide-ranging, given its "platform" approach to creating partnerships, and are typically "middle-out" to "bottom-up". This versatile "platform" facilitates collaboration regardless of the initiating party (e.g. city government, AIM, technology provider, research institution, community, etc.). Combined with the city's continual learning efforts and feedback loops through the documentation and sharing of its initiatives, the platform positions the city well to tackle and handle multiple types and scales of initiatives. In addition, the "Smart Work Centers" implemented by CISCO stand out in comparison against many of the other cities' initiatives examined. While other cities focus on the city management and operational issues and the efficiency in delivery of city services, the "Smart Work Center" initiative has the potential to help citizens transform their living and working activity patterns, i.e. the very nature of urban living and working. Hence, instead of reducing travel times through good traffic predictions and information dissemination, it aims to reduce the need for travel.

Stockholm's initiatives range from "top-down" (e.g. Stokab's network infrastructure) to "middle-out" (e.g. Stockholm Royal Seaport). Its partnership framework for Stockholm Royal Seaport, including multiple technology providers, a research institution and the community, as well as its feedback mechanism through its sustainability assessment unit, is designed to support the medium-to-longer processes involved in developing the district. Hence, like Amsterdam, the city is experienced and well equipped to initiate, implement and innovate new initiatives of different scales.

Different Approaches: Nature of "Smart" Initiatives

The "smart" initiatives undertaken by the cities examined are different in nature, ranging from city-wide ICT infrastructure, to mobile citizen engagement apps, to the planning and implementation of new districts and neighborhoods (see Table 11). As such, it is conceptually challenging to directly compare "smart" initiatives, for example, whether the benefits in a operations center like Rio de Janeiro's COR are "better" or more "cost-effective" compared to that achieved through a local partnership of entrepreneurs like Amsterdam's "Climate Street". However, one pertinent question will be, for the types of initiatives examined, whether there are approaches more characteristic of, or suitable for specific types of initiatives? For similar initiatives, are there approaches of certain cities that are more holistic?

Examples of types of "smart" initiatives and cities' approaches				
Community Engagement Platform	*Web and / or mobile apps for citizen engagement, improved delivery of city services*	*Programs, web and / or mobile apps and portals, to meet city's environmental, economic and social goals*	*New district or city-scale infrastructure and / or ICT system, may involve city-level or agency-level organizational change*	*New district or city-scale infrastructure, involving multi-dimensions, such as energy, waste management, mobility, ICTs, etc. May involve city-level or agency-level organizational change*
Community PlanIT, Boston	Unhackathon / Summer of Smart, San Francisco; Discover BPS / School Choice, Boston; Citizens Connect, Boston; Up Singapore	SF Energy Map, San Francisco;	COR, Rio de Janeiro; Stokab network infrastructure, Stockholm; Smart Work Centers, Amsterdam	Stockholm Royal Seaport; Jurong Lake District, Singapore; Almere Smart Society, Amsterdam; Climate Street, Amsterdam

Table 11 - Examples of types of "smart" initiatives and cities' approaches

"Smart" and "Smarter"? Location-based Infrastructure Initiatives

In the development of city or district-wide infrastructure involving multi-dimensions such as energy, waste, management, mobility, ICTs, etc., the approaches taken by the cities and for each of the projects can be compared. For example, the Stockholm Royal Seaport, Singapore's Jurong Lake District and Amsterdam's Almere Smart Society initiatives all involve the development of new districts with a sustainability focus. Based on the data examined, the approaches of Singapore and Amsterdam appear similar, involving a "middle-out" approach whereby the cities' economic development agencies facilitate and form, or intend to form, partnerships with technology providers to address specific urban issues. In comparison, based on a similar context, Stockholm's approach involves a few additional elements; the partnership with a research institution, Swedish ICT, engaging the future community as part of its data collection and evaluation feedback mechanism, and the set up of a new sustainability unit to assess the efforts. Whilst this study is unable to assess the results of the cities' efforts, Stockholm's approach appears to more holistic, and arguably, "smarter".

Community-Focused Initiatives

In examining other different "smart" initiatives, it is noted that a number of them - e.g. Boston's "Community PlanIT", "Discover BOS", "School Choice", "Citizens Connect", San Francisco's "Unhackathon", "Summer of Smart", and "Up Singapore" - share the similarities of involving web or mobile apps in community engagement, improving delivery of city services, providing better information, etc. Compared to city-wide infrastructure, these initiatives generally require less capital resources to implement. In addition, they generally involve the community in their conceptualization and idea-generation, implementation and use. Hence, it is not surprising that cities naturally take "middle-out" to "bottom-up" approaches for these community-focused initiatives, compared to "middle-out" to "top-down" approaches for city-wide infrastructure.

Interchangeable in Application?

Given the above, one question is whether the approaches are "interchangeable" in application. For example, can Boston's "middle-out" or "bottom-up" approach for a community-focused initiative be applied for an infrastructure project like Rio de Janeiro's COR? It will appear to be unlikely; whilst a range of innovative ideas on emergency response and traffic management may be generated from a "bottom-up" crowdsourcing exercise, a high degree of expertise is needed for implementation, integrating the elements involved (e.g. weather sensors, predictive analysis, process triggers, notifications, front and backend hardware and software, etc.). This often requires large single technology providers with the capabilities or a consortium of smaller technology providers. In the specific context of Rio de Janeiro, where the integration of many city departments is needed (i.e. processes, command hierarchies, manpower organization, etc.), one could also argue that the "top-down" approach would be more suited to ensure the seamless reorganization.

Conversely, it will be doubtful that Rio de Janeiro's "top-down" approach can be effective in the conceptualization and implementation of a community-focused initiative like "Citizens Connect". First, a "top-down" approach is incompatible with the philosophy of the intention, to engage citizens. Second, given the nature of the initiative to solicit citizens feedback and input, the design of the user interface and interactions with the technology will typically require iterations of beta testing with volunteers, as seen in Boston's case, before the initiative is publicly launched. Community inputs are often necessary for fine-tuning to determine what actually "works" for the community; a process which cannot be achieved in a "top-down" approach, however confident the city agency may be of "understanding" its community.

As described earlier, there may be opportunities for a city like Boston to explore how its established approach and know-how of idea generation, innovation and implementation, and citizen engagement may be scaled up to cater to possible

future large-scale "smart" initiatives. Given that a "top-down" approach cannot be easily and interchangeably applied, a litmus test for a "smart" city like Boston may be for it to translate its "smart" approach for its current scale and sectors of application, for application to initiatives of larger scales and higher levels of capital investment, while not losing the substance of its original approach.

Different Approaches: Do cities gravitate to certain models?

The broad categories of the different types of initiatives – i.e. location-based infrastructure, community-focused initiatives, etc. – and the difficulty in the interchangeability of approaches give rise to the question whether cities gravitate towards specific models owing to their specific contexts. For example, in terms of organization and funding, a city with a limited capital budget or human resources may need to rely on a "bottom-up" or "middle-out" approach to harness further resources from collaborative partnerships, such as in the case of Boston's MONUM. In terms of expertise, a city agency or department that embodies a high degree of expertise related to its specific purview, function and / or regulatory powers, may choose a more "top-down" model, such as in the case of Singapore's LTA or Stockholm's Stokab. In terms of scale, location-based initiatives involving city or district-wide infrastructure tend to be more "middle-out" in nature, such as in the case of Stockholm Royal Seaport and Singapore's Jurong Lake District. In terms of city agency goals and objectives, it appears that economic-driven agencies such as Singapore's EDB and Amsterdam's AIM rely more on a "middle-out" approach to generate prototypical urban solutions. Thus, in drawing out lessons for planners, Chapter 5 will consider some of these factors in providing possible "pathways" for cities.

Phasing and Evolution

Comparing the three location-based initiatives (i.e. Stockholm Royal Seaport, Singapore's Jurong Lake District and Amsterdam's Almere Smart Society) to a smaller scale initiative, Amsterdam's "Climate Street", it is noted that the former mainly involve the development of new growth districts, while "Climate Street" relates to the efforts of an existing shopping street; hence, the deeper involvement of the local community, i.e. entrepreneurs and local technology providers. This highlights another observation in examining cities' approaches relating to phasing and development; a partnership approach may evolve as the nature of the project and its context evolves.

On one hand, it is plausible that for development areas such as Singapore's Jurong Lake District and Amsterdam's Almere Smart Society, after the key initiatives are implemented, the cities' approach may evolve and the involvement of the local community broadened. For example, this could be similar to that of "Climate Street", where the community plays a major role in the organization and

management of the "smart" efforts, or similar to "Ijburg You Decide", where the community is engaged for its opinions and feedback. On the other hand, one may question whether the city, at the onset, could already conceptualize such a broader partnership framework that would carry its efforts through different phases of the project.

Technology and Technology Providers' Business Models

Finally, in examining the different approaches, the influence and nature of the technology and technology providers' business models cannot be overlooked. For example, Rio de Janeiro's COR, Amsterdam's "Smart Work Centers" and Stockholm's Stokab network infrastructure share some similarities in the nature of the projects, involving the implementation of ICTs at a city-wide level by single technology providers, i.e. IBM, Cisco, and Stokab, respectively. However, there are different characteristics.

IBM's partnership with Rio de Janeiro focuses on the use of its "system of systems" integration and computing technology to integrate city functions and address the city's problems. In this turnkey model, the technology provider brings forth its technology with its innovations and systems integration capabilities, and combines them with reorganization of city processes to form new solutions. Hence, this model also involves the partnership of a city that shares common goals, and is willing to make large capital investments and organizational changes; this is characteristic of the "top-down" approaches seen in the cities examined.

Cisco's partnership with facility owners, managers, and the city, focuses on the use of its TelePresence networking technology to rethink the nature of work and commuting, and "transform urban centers into networked communities" (Cisco 2012a). Cisco's model brings forth its technology to cities and applies new solutions to issues that may not be already fully recognized as problems. By doing so, it is investing in potential new areas where cities may find benefits (e.g. greater efficiencies and productivity, and reduced negative impacts from commuting), and thus creating new markets in which it will have a headstart.

Stokab, a city-created agency-cum-technology provider, focuses on the provision of backbone infrastructure that is critical to and underpins other "smart" initiatives. In this model, Stokab implements the prerequisite base technology infrastructure with the understanding that this base infrastructure will support other future initiatives and open up new opportunities. This model also encompasses the idea of "sequencing" or "layering", whereby new technologies require a certain level of investment in prerequisite infrastructure before they can be incorporated. In addition, this idea of "sequencing" is also close to the idea that "if you build it, they will come", whereby cities undertake investments in prerequisite infrastructure in view of medium to longer term objectives of attracting new technology, economic investments and business possibilities.

Given the different models undertaken by the technology providers, Chapter 5 will further examine how cities may consider them.

Chapter 5 – Lessons for Planners & Conclusion

Based on the analyses of the cities examined, their different contexts and approaches, it is seen that there is not a single model for cities to implement "smart" initiatives. This chapter suggests a number of best practices and lessons for planners organized around the four theories examined, as well as a summary framework for cities to consider different pathways in their conceptualization of and strategies for implementing "smart" initiatives.

Theory A - In the age of the Smart Machine: Smart Machines and Organization

The "smart city" involves the use of ICTs for automation and intelligent functions, and is also "smart" about the way its processes, organization and governance can be reorganized to take advantage of these technologies.

A1. Identify "smart machine" automation and intelligence functions within and across city agencies

One of the first steps is for cities to identify possible "smart machine" automation and intelligence functions within their multi-scale and multi-faceted roles of planning, management and governance for speedier workflow and more accurate and reliable results. This will involve the efforts of each individual city agency, cascading down to individual departments in each agency (see Figure 49). In addition, cross-department and cross-agency functions should also be examined. Such efforts are typically more explicit in cross-agency projects involving multi-agency collaboration, for example, in a new development area like Stockholm Royal Seaport or Singapore's Jurong Lake District. However, cross-agency functions in daily operations and management, as well as longer-term planning, are also important and potentially overlooked. For example, in the case of traffic management, data from traffic sensors and predictions may be extended beyond the domains of transport authorities and be integrated with other agencies' functions including land use planning (e.g. impacts of land use of transit-oriented developments), urban design (e.g. pedestrian flows), energy and environmental assessment and regulation (e.g. CO2e and particulate emissions arising from traffic), etc., to facilitate automated analyses and scenario-making that inform decision-making. Having identified the functions, cities will need to assess the infrastructure and processes for data collection, integration, interpretation and analysis, as well as structures of behaviors and rules, which typically accompany "smart machine" automation and intelligence functions.

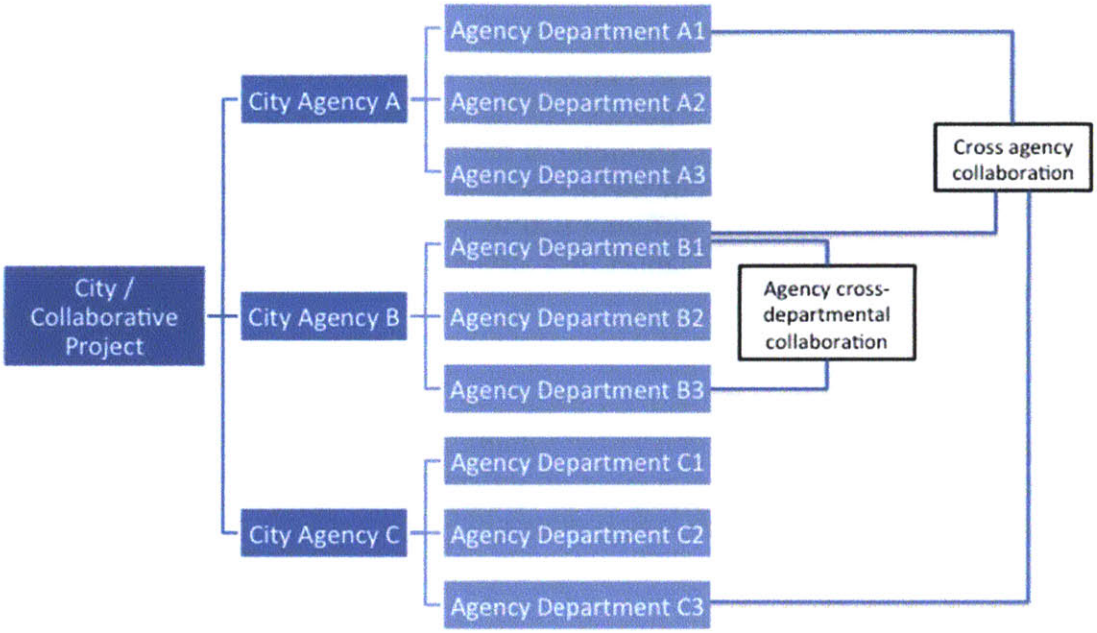

Figure 49 – Cross-Departmental / Cross-Agency Collaboration

A2. Identify complementary informating functions

Related to the above, cities can identify complementary informating functions, whereby reorganization can be made at the cross-agency, agency or department levels to harness automation. Using the above example of integrating traffic data and predictions with land use planning, this may involve redefining the roles of transport planners and land use planners, introduce the new dimensions of technology management and spatial data analytics, and integrating these into a new multi-disciplinary roles.

Theory B - Beyond "Smart Machines": Engaging Communities, Organizations & Businesses

The "smart city" involves a collaborative process where city governments engage communities, businesses, research institutions, etc. as partners in a framework that drives innovation and transformation.

B1. Consider the creation of city innovation drivers

As seen in the examples of Boston's MONUM, San Francisco's MOCI and Amsterdam's AIM, the creation of new city-level agencies has played a major role in driving innovation, forming collaborative partnerships and implementing "smart" initiatives. These agencies, which are organizationally independent from the hierarchical structures of agencies, are able to exercise some degree of freedom in

applying ideas and ICTs across the purviews of individual agencies. By employing a "birds-eye" view across agencies' functions, they are also well-positioned to identify opportunities for cross-agency integration, automation and innovation. To be successful, such city-level agencies, which need not be complex setups, should understand the technologies, organization and processes of and across city agencies, as well as being able to initiate and form partnerships with city agencies, technology providers, research institutions and the community. The organizational goals of such new agencies should also be clearly set out, for example, to support city economic, environmental and social objectives.

B2. Implement initiatives to engage citizens and promote participation, increase access to information, and enhance delivery of city services

Cities like Boston that have implemented "smart" initiatives to engage citizens and promote participation (e.g. "Citizens Connect" crowdsourcing input on fixing potholes, "Community PlanIT" platform for participatory planning, etc.) have generated positive responses. In addition, the engagement and participation of the community has expanded available resources (e.g. "Adopt a Hydrant"), extending what city agencies are able to achieve in the delivery of city services, as well as providing innovative ideas beyond the scope of city agencies (e.g. San Francisco's "Unhackathon" / "Summer of Smart"). Hence, citizen engagement and participation is directly relevant and applicable to planning, for example, in using ICTs to communicate and seek community ideas and feedback on development proposals. Cities can also enhance citizens' access to data and information, for example through Open Data portals. This has the potential to spur innovation and crowd source analytics for cities. In addition, apart from open data, allowing public access to specialized information (e.g. "SF Energy Map") supports city objectives, for example in meeting energy and environmental sustainability targets. Citizens' access to data and information also contribute to transparency and knowledge of city governments' efforts, for example, as seen in Boston's "Score Card".

B3. Identify partners and set up partnership framework for each "smart" initiative

A collaboration framework allows cities to leverage human capital and resources. One of the critical steps is for cities to consider possible partners:

a. City agencies and departments – As highlighted earlier, cross-agency and cross-department functions should be examined and the roles within multi-agency collaboration framework defined. For example, this includes funding issues, manpower and resource contributions, but more importantly, framing the objectives and integrating the "smart" functions with existing processes, creating multiple feedback loops and opportunities to learn.

b. Technology providers – From the cities examined, Table 12 shows a number of technology providers associated with different types of "smart" initiatives. In addition, in structuring partnerships, cities should also consider the different

business models of technology providers. Will the city be investing in specific technologies, however "turnkey" they may be in meeting current needs, but may face obsolescence in the future? How can a city avoid technological lock-in? How adaptable are the city's agencies and departments to new technology, organization and processes associated with the technology provider's business model? How much capacity and resources do city agencies and departments have to integrate technology on their own, if the roles of technology providers were to be limited? Is the technology provider bringing new disruptive technologies that have the potential to reap greater efficiencies and productivity? Are the technologies opening new areas of focus pertinent to the city's broad objectives? Is sequencing needed, for example, to provide prerequisite backbone infrastructure, and if so, how can technology providers be engaged in the phased implementation process? Will there be technology transfers that may benefit city agencies? Are there policies that may influence the engagement of technology providers, for example, to encourage local entrepreneurship and test-bedding of new technologies?

Examples of types of "smart" initiatives / technology providers			
Web and / or mobile apps for citizen engagement, improved delivery of city services, community participation.	*Backbone technology and infrastructure necessary for development of other initiatives, but may not be in itself turnkey.*	*New emerging or prototype technology that addresses new areas of concern, finding potential benefits and creating new markets. May comprise co-investment and risk-sharing between city and technology provider.*	*Turnkey holistic systems based on a single technology providers' proprietary technology, addressing cities' specific needs, and typically requiring large capital investments.*
Boston's Citizen Connect implemented with local technology provider	Implementation of network infrastructure by Stokab, Stockholm; Data warehousing and integration by DoiT, Boston	Implementation of "Smart Work Centers" in Amsterdam by Cisco; Test-bedding of prototype initiatives by Fortum, Ericsson, Envac, etc. in Stockholm Royal Seaport; Use of problem statements to identify new technology providers in Jurong Lake District, Singapore	Rio de Janeiro's partnership IBM to implement COR

Table 12 - Examples of types of "smart" initiatives / technology providers

c. Research institutions – From the cities' "smart" initiatives examined, research institutions do not appear to play a major role. Are there opportunities for research institutions to support the development of technologies, as well as the evaluation of the results of the initiatives, organization and processes as part of multiple feedback loops?

d. Community – The involvement of the community depends largely on the nature of the project. For example, are the "smart" initiatives intended as new infrastructure, which typically require less direct citizen involvement, or citizen engagement tools, where community beta testing and feedback have been shown to be beneficial?

B4. Identify appropriate approach to initiate "smart" project and engage partners

The cities examined have taken a variety of approaches, from "top-down", "middle-out" to "bottom-up"; this is an important consideration in the initiation and implementation of the "smart" initiatives, as well as in the structuring of their partnership frameworks. Knowing and identifying the appropriate approach can help cities and their partners implement and deliver their initiatives appropriately.

For example, the lack of interchangeability in type of approach was seen earlier in the brief comparison between Rio de Janeiro's "top-down" approach for an infrastructure project and Boston's "middle-out" or "bottom-up" approach for a community engagement initiative. In the context of Rio de Janeiro's COR, the "top-down" approach delivered the new infrastructure that integrated many elements (e.g. weather sensors, predictive analysis, process triggers, notifications, front and backend hardware and software, etc.) and reorganized multiple city agencies and their processes. A learning point is that the "top-down" approach appears to be suited for the implementation of city-wide infrastructure involving very clear goals, a short timeline and few options between different technology providers and their technologies.

A consideration between choosing a "top-down" or a "middle-out" approach will be whether more richness in technology, innovation and ideas can be achieved through a "middle-out" approach, as seen in the approaches of other city-wide infrastructure projects such as Stockholm Royal Seaport, Singapore's Jurong Lake District and Amsterdam's Almere Smart Society. In these examples, the cities worked with a larger base of technology providers across multiple sectors and took a more open, flexible test-bedding approach allowing room for more discovery, and which often had a longer development timeframe. Another consideration is that the more open "middle-out" approach may allow cities to change technology providers and their technologies, responding to evolving conditions, and be more resilient in the face of change over the longer-term. For cities considering such a "middle-out" approach, it must be noted that in these examples, the city agencies played an important role in establishing the "first steps" of their initiatives, such as framing the problem statements, identifying areas to address, setting long-term economic, environmental and social sustainability goals, initiating and implementing backbone infrastructure, etc.

From examining Boston's "Citizens Connect" and "Community PlanIT" examples earlier, as well as some of the idea-generating platforms like San Francisco's

"Unhackathon" and "Summer of Smart", such "smart" initiatives thrived from a "bottom-up" approach. This is given the inherent nature of such initiatives, which focus on government-citizen interactions and soliciting inputs from a broad community base. Hence, for cities considering such initiatives, a "bottom-up" approach has been shown to foster innovation and creativity outside of the domains of city governments.

B5. Identify avenues to avoid lock-in

A consideration for cities, in the conceptualization of their "smart" initiatives, is to identify avenues to avoid lock-in. This could be through the use of open data and open source platforms instead of proprietary data formats, as seen in the examples of cities like Boston, San Francisco and Amsterdam, and in the structuring of partnerships across various initiatives, where not a single technology provider or technology dominates. In the example of Stockholm Royal Seaport, the implementation of "generic infrastructure" (Stockholm Royal Seaport 2013) aims to promote innovation and flexibility; such an approach allows cities to remain open and flexible in the longer term, evolving the partnership framework and choice of technology and technology providers to meet changing needs, and to create and maintain a more sustainable, creative environment.

B6. Anticipate possible challenges in collaboration and identify solutions

Learning from the cities examined, cities embarking on collaborations should anticipate possible challenges arising from these partnerships, i.e. between partners, as well as arising from technology gaps. For example, San Francisco's "bottom-up" efforts to crowdsource ideas through hackathons were seen to be inadequate as city agencies were perceived to be unresponsive towards community inputs. Hence, in structuring partnership frameworks, cities should be mindful of the need for close collaboration, involving clear communication, streamlining and integrating processes between partners. This is in addition to defining clear common objectives, and closing gaps such as different levels of ambition (e.g. as seen in Singapore's case), different modes of operation (e.g. as seen in Boston's case where some departments are more technology-driven, compared to more operational-focused ones), and problems of system and data inoperability (e.g. as seen in Rio de Janeiro's case). In many of these examples, the "human element" was cited as the critical factor in maintaining close collaboration and closing gaps; hence this critical dimension should be a key element for cities' partnership frameworks.

Theory C - Cities that Learn, Relearn and Adapt

The "smart city" learns, relearns and adapts itself, through learning networks, as well as using metrics, monitoring and feedback processes.

C1. Establish avenues for continual learning

Continual learning, as well as sharing experiences, is a trait of the "smart" cities examined. Through avenues such as international and regional conferences, city networks, learning visits, as well as publications, cities are able to learn best practices from each other, to continually innovate and apply "smart" initiatives for their specific contexts. Through these avenues, some secondary effects for the "smart" cities were also observed, for example, through Amsterdam's detailed documentation of its "smart" efforts, it is recognized as a thought leader in the field. Singapore's trade show at the World Cities Summit provides business opportunities for its technology providers to showcase their "smart" solutions.

C2. Establish and use metrics

An important consideration for cities is to establish and use to assess the effectiveness of their "smart" initiatives against wider city objectives, for example, to help meet environmental, economic or social sustainability targets. The types of metrics range widely depending on the nature of the project, for example, from the number of citizen participants in community engagement projects such as Boston's "Citizens Connect" and "Community PlanIT", to reductions in operational times for emergency response units in Rio de Janeiro, to reductions in energy use and CO2e for new developments in Amsterdam's "Geuzenveld Sustainable Neighborhood". The metrics should be defined early in the conceptualization of the initiatives, enabling the necessary feedback mechanisms to be incorporated by the technology providers and partners. For example, in the case of Stockholm Royal Seaport, physical instrumentation is planned for new developments, and the monitoring and data collection efforts will also require the organizational processes to be put in place, e.g. by-laws or agreements requiring residents or property managers to regularly submit data. Where necessary, this may also involve new agencies such as an independent assessment unit similar to Stockholm's example. On another level, cities may also consider the use of metrics to assess their processes of implementation, similar to Boston's "action research" approach, to help improve the process of implementation as well as the actual initiatives involved.

C3. Incorporate multiple, multi-scale feedback loops

Related to the use of the metrics, the planning and incorporation of multiple, multi-scale feedback loops is an important consideration. Feedback loops internally allow the continual assessment of the effectiveness of the initiatives, and externally, link the initiatives to other processes which are broader in scope, cross-agency (e.g. in Singapore's case, integrated transportation and land use planning) and over different time-scales. As seen in Amsterdam's case, feedback arising from initiatives also had an impact on local policies. Thus, the use of feedback loops has potential for cities to reap both primary (directly arising from the initiatives) and secondary (influence on other processes) benefits, and also links the multi-faceted dimensions of governance, for example, short-term city management operations with longer-

term land use and infrastructure planning. In the case of Stockholm Royal Seaport, the concept of feedback loops is boldly extended to encompass multi-directions; on one hand the application of technology is planned to positively influence and change the context, on the other hand, the evolving context may require the redesign, modification and even abandonment of technology.

Theory D - Investing for the future

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

D1. Establish clear objectives, and assess investments against ROI

With clear metrics defined and feedback loops established, cities will be better equipped to assess the effectiveness of their "smart" initiatives vis-à-vis city objectives and targets. Even at the early planning and conceptualization stages, defining the metrics will help guide cities to set goals and estimate the ROI, from both a financial and non-financial perspective (as seen in some of the cities examined), evaluate the cost-benefits of their proposed "smart" initiatives and justify their investments. In addition, cities may consider elements of risk and vulnerability to disruptions in their cost-benefits analyses, especially for mission-critical functions such as real-time traffic and emergency response management. For instance, initiatives involving infrastructure and utilities (e.g. smart grids) and their related backend systems may be vulnerable to disruptions arising from cyber-attacks given their dependency on networks[6]. Hence, the investments in such "smart" initiatives may also need to consider protection and redundancy, etc.

D2. Define and pursue long-term, wider benefits instead of short-term ones

From the cities examined, there was no evidence that they directly monetize their "smart" initiatives, for example, through the sale of data. Instead, cities such as Boston, San Francisco, Amsterdam and Stockholm have taken an open data approach, being aware of the longer-term benefits of spurring innovation, improving city services and enhancing community engagement. Thus, a long-term view towards gaining wider benefits is important for cities in conceptualizing and implementing their "smart" initiatives. This often requires cities to define their short-term, medium-term and longer-term objectives for the initiatives, to ensure that there is net benefit and minimized conflict between these goals. In particular, for initiatives involving new development areas like Stockholm Royal Seaport and Singapore's Jurong Lake District, the implementation of infrastructure and

[6] For the 2012 fiscal year, the U.S. Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) received and responded to a total of 198 incidents in the U.S., including 82 attacks on the energy sector, 7 attacks on the government sector, 5 attacks on the transportation sector, etc (ICS-CERT 2012).

development require longer time-frames compared to less complex initiatives such as a web or mobile app. Thus, the continual monitoring and use of multiple multi-scale feedback loops within a well-established multi-timeframe road map will ensure that cities remain on track.

D3. Sequence development and investment of "smart" initiatives

Having a multi-timeframe road map also allows cities to sequence the development and investment of their "smart" initiatives, in particular where prerequisite backbone infrastructure is required (e.g. in the case of Stockholm's Stokab network infrastructure) before other initiatives can be implemented. In such cases, where new technologies may not be able to be "leapfrogged" in, the conceptualization of the "smart" initiatives will require the sequenced development of organization and processes (e.g. creation of new agencies / departments, analysis and retooling of existing functions and processes, structuring partnership frameworks etc.) and infrastructure (e.g. backbone network infrastructure, backend servers, core mapping systems, etc.). Sequencing the development of "smart" initiatives will also allow cities to assess and address pertinent questions, for example, whether specific technologies are ripe, how much time specific technologies need for test-bedding, etc.

"Pathways" for Cities

From the above considerations and earlier analysis that different approaches tend to be associated with specific characteristics, cities may find different possible "pathways" in their conceptualization and implementation of "smart" initiatives.

For example, a city may display characteristics that appear to lead to a "top-down" approach. It may be involved in the implementation of large-scale infrastructure, have a rigid partnership engagement with a technology provider that has a high level of expertise and ability to integrate multiple, multi-scale functions, and its focus may be on the application of ICTs for automation, etc. Learning from the cases examined, there is opportunity for such a city to maximize its opportunities for combining "informating" and reorganization with its "smart" automation functions, incorporating multiple, multi-scale feedback mechanisms, taking a long-term view towards reaping maximum benefits through knowledge transfers, sequential infrastructure development and encouraging innovation, creating cross-silo benefits from the application of ICTs, as well as remaining open and flexible in terms of technology and partnership structures to avoid lock-in, etc. In other words, this city does not need to be constrained by a traditional "top-down" approach that narrowly seeks solutions to a specific set of problems; instead, it can take a "smarter" approach in its investments by recognizing, creating and harnessing positive spillover effects.

Another city may display characteristics that appear to lead to a "bottom-up" approach, for example, having a limited city budget, resources and in-house expertise to engage in large-scale turnkey projects, and / or having an entrepreneurial grassroots that actively seeks solutions, etc. Yet some of the grassroots-driven efforts, while innovative, may be fragile and unsustainable if robust partnerships with city governments are not put in place, or if a longer-term framework is not well established (e.g. attention to city data use and management, data and systems interoperability, knowledge sharing between partners and city agencies, etc.). Such a city can thus focus on developing the appropriate partnership framework, communication channels and collaborative platforms, upon which processes of innovation, knowledge sharing and bringing ideas to fruition are made sustainable in the long-term. To harness the grassroots-driven innovative and disruptive efforts, the city can also facilitate access to open data and develop a supportive regulatory environment.

Finally, another city may be inclined to adopt the "middle-out" approach of defining issues while encouraging openness for partners to develop solutions, through an innovation and entrepreneurship focused city agency / department. While one may argue that such a city may not achieve the deep technological benefits of a "top-down" turnkey approach, or the level of innovation of a "bottom-up" grassroots approach, however, as seen from the cases and "smart" initiatives examined, the cities that have adopted the "middle-out" approach appear to have made conscious decisions that are mindful of sustaining long-term partnerships and reaping wider benefits. For these cities, the "middle-out" approach may be a balanced model that involves exercising appropriate city leadership to tap and work with the expertise and inputs of technology providers, research institutions and the community. The "middle-out" approach has also been seen to be versatile, being able to be applied to different initiatives ranging from smaller-scale community-engagement efforts to larger-scale location-based infrastructure projects. Thus, such a city can concentrate on developing its collaborative platform where strong partnerships between the city government, technology providers, research institutions, and the community can flourish. It can also gradually upscale its "middle-out" initiatives, through systematic feedback and learning from the performance of its initiatives as well as the processes of collaboration and implementation.

Conclusion

Recognizing the increasing global trend in cities branding themselves as, or striving to become "smart cities", this study sought to understand more about what "smart" cities encompass. Whilst a common theme in "smart" cities lies in the application of technology to city planning and management that leads to greater optimization of time and resources, an unclear definition could lead to possible image or technological traps, heavy investments in ICTs and infrastructure without recognizing fuller potentials of being "really smart", or focus on "smart" technologies for short-term solutions without adequately considering the longer-

term. Given the "smart" prefixing trend in planning circles, and more critically, the raised consciousness in policy-makers' minds, addressing these issues was seen as timely. This is also considering that cities are today grappling with goals and plans for sustainable development, resource management and climate change mitigation, and in many cases rapid urbanization; thus learning about being "smart" and how to be "smart" in planning and for planners will be invaluable.

Through literature review on theories of being "smart", a survey on cities' efforts and the efforts of major technology providers, a background understanding of "smart cities" was established. Four main theories were identified, around which a framework for analysis was drawn:

- In the age of the Smart Machine: Smart Machines and Organization;
- Beyond "Smart Machines": Engaging Communities, Organizations & Businesses;
- Cities that Learn, Relearn and Adapt; and
- Investing for the future.

The study examined the efforts of six cities - Boston, San Francisco, Amsterdam, Stockholm, Singapore and Rio de Janeiro – assessing planners' perceptions and concepts of "smart cities" and their "smart" initiatives. The research was made through phone and email interviews with city officials and representatives from key city agencies, as well as from secondary data sources such as city publications, reports, news articles, etc.

The research results showed that overall, the cities' concepts and perceptions of "smart cities" were supportive of the four main theories of being "smart", i.e. the "smart cities" generally show characteristics of elements described under the theories, albeit having them in various degrees and combinations. These four theories of being "smart" were found to be complementary and not mutually exclusive; many of the cities examined recognized and adopted various elements according to and in response to their specific contexts. Hence, the cities had diverse approaches, ranging from "top-down" to "middle-out" and "bottom-up", and different partnership frameworks involving city agencies / departments, technology providers, research institutions and the community, which varied according to the nature of the initiatives. From the cities examined, it appeared that for initiatives that involved location-based infrastructure, a "top-down" to "middle-out" approach was more commonly taken, compared to a "bottom-up" to "middle-out" approach for initiatives involving community engagement. In the former category, from some examples where a "middle-out" instead of "top-down" approach was taken, there appeared to be a greater awareness of the long-term sustainability of the partnership and initiative.

In conclusion, from analyzing the cities' efforts, being "smart" is not only about harnessing the best ICTs to achieve optimum results and meet city economic,

environmental and social objectives. It involves careful organization within and across city agencies and departments to complement new technologies and to form sustainable partnerships with technology providers, research institutions and the community. It also encompasses prudent decision-making that matches a city's resources and capabilities with its objectives in the conceptualization and implementation of "smart" initiatives, maximizing potential benefits for the longer-term, while maintaining a flexible and open approach that fosters innovation. Being "smart" also involves continual learning and feedback monitoring, for cities to remain aware and nimble, through their own and others' experiences. Finally, being "smart" involves recognizing a combination of the above elements, and not being limited to approaching city issues from only one of them. These attributes all involve commitment and leadership from city leaders, agencies and departments.

With the learning points highlighted, this study aims to serve as an applicable guide for city planners to consider the various theories and best practices, as they embark on their "smart" initiatives.

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ryan/2011/11/17/observations-from-a-%E2%80%9Csmarter%E2%80%9D-operations-center-in-rio-de-janeiro/ [Accessed April 2, 2013].

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Appendix 1: A Survey of Smart Cities

City / State / Country	Application / Initiatives	Technology Provider(s)	References
North America			
Holyoke, Massachusetts, U.S.A.	*OneHolyoke*: Massachusetts Green High Performance Computer Center; Integrated police & fire radio interoperability system; after-school education; smart work centers	Cisco	http://newsroom.cisco.com/dlls/2010/prod_101410.html http://www.fastcompany.com/1546430/cisco-plans-make-massachusetts-city-smarter-rather-build-one-scratch
Burlington, Ontario, Canada	GridSmartCity: smart grid with 'seaf healing grid'; quick charge DC electric vehicles charging stations; renewable energy		http://gridsmartcity.com/ https://www.intelligentcommunity.org/index.php?src=gendocs&ref=Smart21_2007&category=Events
Dubuque, Iowa, U.S.A.	*Smarter Sustainable Dubuque*: Smart water meters; water, electricity & transportation management system; community engagement & education; energy efficient municipal services & buildings; community tools	IBM	http://www.cityofdubuque.org/index.aspx?NID=1344 http://smartcitiesblog.com/2011/12/14/more-on-dubuque-the-smart-city/
San Diego, California, U.S.A.	*Smart City San Diego*: Car2Go electric vehicle sharing with PV canopy charging station; smart grid with smart meters and smart appliances and customer demand response; renewable energy research & economic development	San Deigo Gas & Electric GE CleanTECH	http://smartcitysd.org/ http://www.earthtechling.com/2012/01/san-diego-makes-smart-city-moves/
Syracuse, New York, U.S.A.	Software-based planning tool to predict problems with vacant housing & allocate resources efficiently	IBM	http://www.syracuse.com/news/index.ssf/2011/03/syracuse_named_one_of_ibms_sma.html http://smartercitieschallenge.org/city_syracuse_ny.html
Wilmington, North Carolina, U.S.A.	Fiber optic network; wireless technology using TV white spaces for environmental monitoring, traffic monitoring & management, remote facilities lighting management	Spectrum Bridge	http://downtownwilmington.wect.com/news/news/52984-mayor-saffo-wilmington-smart-city http://www.engadget.com/2010/02/26/white-space-smart-city-network-goes-up-in-wilmington-north-ca/
Houston, Texas, U.S.A.	4G municipal wireless broadband network; traffic management, remote monitoring of water meters, city facilities & operations such as video surveillance & parking pay stations; free internet service for underserved communities	IBM Alvarion	http://urgentcomm.com/networks_and_systems/mag/houston-smart-city-initiative-201011 http://www.bizjournals.com/houston/news/2012/03/15/houston-receives-ibm-2012-smarter.html
Alcoa, Tennessee, U.S.A.	*GridSmart:* real-time traffic management system	Aldis	http://www.itsa.org/awards-media/press-releases/911-alcoa_named_%E2%80%9Csmart_city%E2%80%9D_by_the_intelligent_transportation_society_of_america_for_deployment_of_smart_technologies_to_address_local_transportation_challenges
Portland, Oregon, U.S.A.	*Intelligent Transport Systems* with transit signal priority, advance information systems for accident re-routing; *System Dynamics* interactive modeling of city systems	IBM (systems dynamics)	http://smartercities.nrdc.org/city-stories/city-profiles/large/portland-oregon#tk-city-profile http://www-03.ibm.com/press/us/en/pressrelease/35206.wss
Chattanooga, Tennessee, U.S.A.	Fastest gigabit broadband fiber optic network in the U.S.; Smart grid with smart meters	EPB	http://chattanoogagig.com/ http://www.machinetomachinemagazine.com/2012/01/21/smart-cities-today%E2%80%99s-difference-tomorrow%E2%80%99s-ideas/
Dublin, Ohio, U.S.A.	*Dublink* fiber optic network & Central Ohio Research Network; Dublin Entrepreneurial center		http://dublin.oh.us/econdev/smart21.php
Stratford, Ontario, Canada	*Stratford Smart City*: High speed internet access aiding education, government services; smart meters	Motorola	http://www.city.stratford.on.ca/newslink/award_smartcity.asp http://stratfordsmartcity.ca/
Windsor-Essex, Ontario, Canada	*Smart Community Portal* with citizen services & community engagement; Broadband access, high speed connectivity for health & medical school	IBM	http://www-03.ibm.com/press/us/en/pressrelease/33522.wss
Austin, Texas, U.S.A.	*Pecan Street Project*: Smart grid, electric car infrastructure, solar energy	Austin Energy,	http://smartercities.nrdc.org/city-stories/city-profiles/large/austin-tx

		Pecan Street	http://www.pecanstreet.org/
Boulder, Colorado, U.S.A.	*SmartGridCity*: Smart grid with customer energy management & conservation tools, smart meters, smart substations	Xcel	http://smartgridcity.xcelenergy.com/ http://www.time.com/time/specials/packages/article/0,28804,2026474_2026675_2044302,00.html
Minneapolis, Minnesota, U.S.A.	*Intelligent Operations Platform:* Integrated analytics and visualization for water, traffic, public safety and city operations management; metrics and performance data for city planning.	IBM	http://www.startribune.com/business/123289493.html?refer=y http://smartercities.nrdc.org/city-stories/city-profiles/large/minneapolis-minnesota#tk-city-profile
Boston, Massachusetts, U.S.A.	*Innovation District* and *Mayor's Office of New Urban Mechanics* to cultivate civic & private sector collaboration in innovation; online game-like platform to engage community in policy & planning; web-based "Adopt a Hydrant" community program; Smarter Cities Challenge Grant traffic management	IBM (traffic management)	http://www.newurbanmechanics.org/ http://www.cityofboston.gov/news/default.aspx?id=5516
San Francisco, California, U.S.A.	1st U.S. city to pass open data legislation and platform DataSF, encouraging app building; 1st U.S. city to designate Chief Innovation Officer; ideation platforms connecting citizen problems to civic challenges; online solar energy potential assessment tool; smart grid; waste reduction RecycleWhere; renewable SF EnergyMap; ChargePoint EV network		http://smartercities.nrdc.org/city-stories/city-profiles/large/san-francisco-california#tk-city-profile http://www.sfenvironment.org/news/update/designing-a-smarter-and-more-sustainable-san-francisco
South Bend, Indiana, U.S.A.	Data center and telecommunications carriers hub; fast fiber optic network; redundant electrical network; intelligent sewer system with sensors; Intelligent Operations Center (IOC)	IBM (IOC)	http://www.wsbt.com/news/wsbt-south-bend-makes-list-of-smart-cities-20120807,0,6106356.story?track=rss http://www-03.ibm.com/press/us/en/pressrelease/38153.wss
Reno,	City geo-spatial systems analytics to facilitate economic development	IBM	http://www.ktvn.com/story/20097953/ibm-names-city-of-reno-smart-city
South America			
Rio de Janerio, Brazil	*Rio Operations Center*: Integrated real-time city operations / command center coordinating emergency & security services, flood prediction, traffic, city event management, etc. for over 30 city agencies; real-time twitter information stream to citizens	IBM	http://www.rj.gov.br/web/guest http://www.rio.rj.gov.br/web/corio http://www.nytimes.com/2012/03/04/business/ibm-takes-smarter-cities-concept-to-rio-de-janeiro.html?pagewanted=all http://www.wired.com/beyond_the_beyond/2011/11/ibm-smart-cities-in-rio-de-janeiro/
Europe			
Malta	*SmartCity Malta*: Informational & technology business park, with redundant ICT network & reliable energy supply, high LEED standards building design,	IBM (energy)	http://malta.smartcity.ae/
Amsterdam, Netherlands	*Amsterdam Smart City*: "Climate Street" collective effort of centralized logistics, dimming public lighting, smart metering; "Smart Working Centers" hot-desk working facilities replacing offices; energy monitoring & management; citizen engagement apps; "Car2Go"electric car rental; "Ecomap" neighborhood emissions information	Liander KPN Cisco	http://amsterdamsmartcity.com/
Dublin, Ireland	*Sustainable Connected Cities – Dublin*: "City watch" & "City sensing" real-time urban monitoring, citizen participation. IBM *Smarter Cities Technology Center* to research, develop & commercialize smart city systems	Intel IBM (Technology Center)	http://www.siliconrepublic.com/clean-tech/item/29527-intel-labs-spearheads-strat http://www-03.ibm.com/press/us/en/pressrelease/29745.wss
Glasgow, Scotland, U.K,	Open source Smart Cities search engine of "smart urban environment" camera & microphone sensors & data analytics; developing low-carbon energy technologies, efficient homes, etc.		http://www.zdnet.com/glasgows-smart-search-engine-senses-cities-4010026366/ http://www.glasgow.gov.uk/en/Business/Environment/Sustainabledevelopment/GlasgownamedanIBMsmartercity.htm
Lyon, France	Smart grids wtih intelligent energy equipement, urban mobility with shared electric vehicles & real-time urban navigation tool, digital citizen services, "agility tools" for public policies	Nedo / Toshiba CNR IBM	http://www.majorcities.eu/workshops/2012-helsinki/helsinki2012_lyon.pdf http://www-03.ibm.com/press/us/en/pressrelease/39440.

	management; transportation analytics & management	(transportation)	wss
Malaga, Spain	*Smart City Malaga*: Intelligent mobility with electric vehicles; smart energy grids; e-government services; smart buildings; environmental intelligence	Endesa	http://www.smartcitymalaga.es/ http://www.endesa.com/en/aboutEndesa/businessLines/principalesproyectos/Malaga_SmartCity
Peterborough, U.K.	Data analytics of energy, water, ecosystem, waste & transportation systems, with online interface for government, utilities & citizens	IBM	http://www.techweekeurope.co.uk/news/peterborough-aims-to-be-most-sustainable-uk-city-thanks-to-tech-5898 http://ukintaiwan.fco.gov.uk/en/news/?view=News&id=531171482
Stockholm, Sweden	Dark fiber network with restructured infrastructure / utility service; public wifi in schools; widespread internet access; public education program for homeless; congestion pricing & traffic management; open traffic data encouraging app development industry; waste heat from broadband switching node to heat school	IBM (transportation) Stockholm	http://international.stockholm.se/-/News-from-the-City-of-Stockholm/News/Stockholm---a-smart-city/ http://www.stokab.se/templates/StandardPage.aspx?id=1223
Edinburgh, Scotland, U.K.	*e-Government Smart City*: ICTs to enhance government customer service, continuous improvement & productivity, deliver public services (e.g. National Entitlement Card), "Planning Portal" citizen engagement, "People's Network" to provide citizen opportunities	BT	http://www.edinburgh.gov.uk/info/691/council_performance/967/e-government_smart_city
Southampton, U.K.	*Smartcities Card*: Multifunctional card (bus pass, donor card, library card, leisure card, toll payment & ID)		http://www.southampton.gov.uk/living/smartcities/ http://www.localgovernmentexecutive.co.uk/feature/southampton-smartcities-citizen-smart-card
Eindhoven, Netherlands	Data & analytics for crime management; "Brainport" collaboration of businesses, scientists & government to promote technology & business development	IBM	http://smartercitieschallenge.org/city_eindhoven_netherlands.html http://eu-smartcities.eu/place/eindhoven
Issy-les-Moulineaux, France	1st district smart grid in France, energy efficiency programs; Urban Planning & Sustainable Development Center with digital tools for public consultation & communication such as the Issy 3D model; augmented reality citizen app; "Pay-by-phone" service; interactive multimedia heritage trail	Microsoft, Bouygues Immobilier, Bouygues Telecom, Schneider Electric, Total, Alstom, ERDF, ETDE, Steria	http://www.issy.com/index.php/fr/english/issy_a_smart_city/issygrid
Luxembourg	*e-City*: "HotCity@net" wifi mesh network; city services apps	Cisco	http://summit2010.uni.lu/publish/100602%20VdL%20Future%20Internet%20def.pdf
Paredes, Portugal	*PlanIT Valley*: Integration of companies, education & government through "Urban Operating System"; traffic management, peak electricity demand, assisted parking, emergency services; monitoring of condition & performance of vehicles & infrastructure; citizen apps; building sensors	Cisco Microsoft	http://uk.reuters.com/article/2011/03/31/idUK349564970420110331 http://living-planit.com/planit_valley.htm
Santander, Spain	*SmartSantander*: Extensive wireless sensor network for traffic sensing and management, parking metering, environmental monitoring (e.g. luminous intensity, temperature, noise level, air quality), parks & gardens management (e.g. irrigation), city information apps, citizen engagement in data collection, deployment of mobile sensors in public vehicles, adaptive street lighting, energy monitoring		http://www.smartsantander.eu/ http://www.smartplanet.com/blog/global-observer/santander-to-become-spains-first-smart-city/4279
Manchester, U.K.	*Manchester Living Lab & SMARTiP*: Citizen engagement in data collection and analytics, participatory planning, smart environment sensors on noise, pollution, temperature, etc.	Local sources	http://www.manchesterdda.com/smartip/ http://cordis.europa.eu/fp7/ict/fire/events/20120921-fire-open-consultation/presentations/scexp-05-smartip.pdf

Birmingham, U.K.	*Smart Connected Birmingham:* "Smart sustainable city" low carbon economic growth; "Smart connected city" technology clusters, open data & public services; "Smart accessible city" new high speed rail, airport runway, metro extension & enterprise zone		http://bigcityplan.birmingham.gov.uk/birmingham-secures-smart-city-broadband-future/ http://birminghamnewsroom.com/2012/07/smart-city-commission-to-lay-future-foundations/
Jatkasaari, Helsinki, Finland	*Low2No*: Sustainable development design for Jatkasaari metropolitan area.		http://www.low2no.org/
Oulu, Finland	*Ubiquitous Oulu Smart City*; Online healthcare database with health research & analytics; Robust broadband connectivity; web-based system on construction & energy-efficient practices; remote house energy monitoring; networks & sensors for mining; GPS dog-tracking system		http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=05765905
Rivas-Vaciamadrid, Spain	Fiber-connected municipal sites; wifi mesh network; remote management of city services (e.g. video surveillance, energy management, public lighting, street furniture, park irrigation); city digital media video center for students		http://www.salicru.com/en/rivasvaciamadrid-en
Barcelona, Spain	*22@Barcelona*: ICT, media, design, bio & energy district with underground utilities corridors; "distri-clima" heating & cooling system; Driverless metro & retrofit hybrid bus. *Live Barcelona* electric vehicle program; Self-sufficient buildings network; smart parking network; municipal water network, etc.	Siemens (transportation) Abertis Agbar Cisco Schneider Electric-Telvent Telefonica	http://www.fastcoexist.com/1679017/barcelona-a-smart-city-model-for-the-planet http://www.majorcities.eu/workshops/2012-helsinki/helsinki2012_barcelona.pdf
Asia-Pacific			
Kochi, India	*SmartCity business park*: Self-sustained industry township for knowledge-based companies		http://www.itmission.kerala.gov.in/general/516-smart-city-kochi.html
Nanjing, China	*Smart Nanjing*: Smart transportation, urban planning, urban safety, water resources management, urban command center, wireless Nanjing, government affairs data center	IBM	http://english.nanjing.gov.cn/zx/szyw/201005/t20100525_296970.htm http://www.chinadaily.com.cn/cndy/2012-06/18/content_15508067.htm
Shenyang, China	Waste water analysis & clean water infrastructure management, reduce carbon emissions & conserve energy, track food supply, intelligent transportation, environmental emergency response	IBM	http://www.china-briefing.com/news/2009/09/18/ibm-yocollaborate-with-shenyang-on-smart-city-project.html http://online.wsj.com/article/SB12531179732316391.html
Sydney, Australia	*Smart Grid, Smart City*: smart grid & metering testbedding; LED street & park lights	GE, Gridnet, IBM, Landis + Gyr	http://www.smartgridsmartcity.com.au/About-Smart-Grid-Smart-City.aspx http://www.cebit.com.au/ausinnovate/2012/smart-cities-city-of-sydney-led-lighting-rollout
Yokohama, Japan	*Yokohama Smart City Project*: Restructured energy infrastructure programme with overall utility grid & energy management system; electric vehicles; building energy management system; home energy management system	Panasonic, Toshiba, Nissan, Tokyo Electric, Tokyo Gas, Meiden	http://www.city.yokohama.lg.jp/ex/mayor/interview/pressroom/newsrelease/h22/newsrelease101102-e.pdf
Chengdu, China	*Chengdu Hi-tech Zone "Tianfu Smart Internet City"*: smart internet industry service, smart internet community service	Cisco	http://www.chinadaily.com.cn/regional/2011-04/29/content_12424602.htm
Guangzhou, China	*Sino-Singapore Guangzhou Knowledge City*: Integrated urban management systems with smart home & building automation systems, smart grid, government administration system, security sensing, transportation, Internet of Things (IOT) utility & health management; "Eco-city" with energy & water efficiency, green transportation system; "Learning city" knowledge economy focus; "Design city"		http://www.ssgkc.com/strategic-initiatives/smart-city/ http://economists-pick-research.hktdc.com/business-news/vp-article/en/1/1X07V2YW.htm
Singapore	*Transportation*: Real-time traffic analytics and	IBM	

	management, route planning and prediction, variable congestion pricing; *"City Cockpit Prototype"*: Real-time analytics and tracking of city processes such as traffic conditions, utilities use and pricing, public facilities, etc.;"Wireless@SG" free public wifi; NFC retail program; e-freight port & logistics operations; National electronic Health Record; Waste water treatment	(transportation) Siemens (City Cockpit, waster water)	
Songdo, S. Korea	*Songdo International Business District*: Extensive internet network & wireless sensors for street lights & buildings; "Telepresence" video conferencing technology in homes, offices, hospitals, shopping centers; smart appliances in homes; integrated building & facility, security management; car RFID traffic analytics & management	Cisco	http://newsroom.cisco.com/press-release-content?type=webcontent&articleId=426592 http://www.songdo.com/
Gujarat, India	*Gujarat International Finance Tec-City*: New financial center with robust urban planning, intelligent transportation system, district cooling system, tech-finance infrastructure & data centers, energy & water management		http://www.firstpost.com/economy/gujarat-showing-the-way-for-indias-smart-cities-172716.html http://articles.economictimes.indiatimes.com/2012-01-05/news/30593348_1_nano-city-gujarat-international-finance-tec-city-waste-collection
Busan, S. Korea	*Ubiquitous Busan*: "Busan Information Highway" application of ICTs on city infrastructure & logistics (e.g. RFID port systems, tourism/convention, health, transportation, disaster prevention); free access wifi zones; "Busan Mobile Application Center"; "Smart Work Center"; RFID children tracking; sensor networks for water & air quality monitoring	Cisco	http://www.cisco.com/web/about/ac79/docs/ps/Busan-Green-u-City_IBSG.pdf http://www.gsma.com/connectedliving/wpcontent/uploads/2012/08/cl_busan_08_121.pdf
Middle-East / Africa			
Johannesburg, South Africa	Growth and Development Strategy 2040: Energy, water & waste management, extended broadband internet network, traffic management, Nasrec technological cluster		http://www.bdlive.co.za/articles/2012/03/28/johannesburg-to-host-african-ict-smart-city http://smartercitieschallenge.org/city_johannesburg_southafrica.html
Masdar, Abu Dhabi	*Masdar City*: Carbon neutral zero-emission city; smart grid; energy management; waste management; water management; transportation with electric buses, cars	GE (energy) Mitsubishi (electric vehicles)	http://www.masdarcity.ae/en/
Cairo, Egypt	*Cairo Smart Village*: ICT hub; sophisticated facility management; fiber optic network; uninterruptible power supply network; "Smart Village Food Court"; "Smart Village Club"; "Smart Nursery"; "Smart International School"		http://www.smart-villages.com/
Dubai, U.A.E.	*Dubai SmartCity*: Online government services; ID card; "Media city"; "Healthcare City"; "Knowledge Village"; "Dubai Internet City" technological hub		http://www.cisco.com/web/learning/le21/le34/downloads/689/nobel/2005/docs/Abdulhakim_Malik.pdf
King Abdullah Economic City, Saudi Arabia	*King Abdullah Economic City*: Technological hub, port, "7-24-60" services; Fiber optics telecommunications network with 'intelligent' services to workplace & home, supporting transportation services	Cisco	http://www.menainfra.com/article/king-abdullah-economic-city/

Compiled by author, 2012-2013. Key data sources:

- *Cities websites and news reports*
- *Smart + Connected Communities Institute, 2012, 2012 Smart Cities Expose: 10 Cities in Transition.*
- *ABI Research, 2011, Smart Cities: Municipal Networking, Communications, Traffic/Transportation, and Energy. Research Report. 110 pages.*
- *Pike Research, 2011, Smart Cities: Intelligent Information and Communications Technology Infrastructure in the Government, Buildings, Transport, and Utility Domains. Research Report. 88 pages.*
- *Wikipedia, 2012, Smart City. en.wikipedia.org/wiki/Smart_city, retrieved 9 September 2012.*

Appendix 2: Selected City Agencies / Departments

Boston, Massachusetts, U.S.A.	
Mayor's Office of New Urban Mechanics (MONUM)	Interview with Mr Chris Osgood on January 23, 2013.
City of Boston Department of Innovation and Technology (DoIT)	Interview with Ms Claire Lane on February 11, 2013.
San Francisco, California, U.S.A.	
San Francisco Department of the Environment (SF ENV)	Interview by email with an SF ENV official on January 13, 2013.
Mayor's Office of Civic Innovation (SF MOCI)	An interview could not be arranged. Data obtained from secondary sources.
Amsterdam, Netherlands	
City of Amsterdam	An interview could not be arranged. Data obtained from secondary sources.
Amsterdam Innovation Motor (AIM)	Interview by phone with an AIM official on January 21, 2013.
Stockholm, Sweden	
City of Stockholm Planning Administration	Interview by email with a City Planning Administration official on January 30, 2013.
Stokab	An interview could not be arranged. Reports obtained from a Stokab official on December 25, 2012.
Singapore	
Economic Development Board (EDB)	Interview by phone with an EDB official on February 20, 2013.
Infocomm Development Authority (IDA)	Interview by phone with Mr Ronnie Tay on January 29, 2013.
Land Transport Authority (LTA)	Interview by phone with a LTA official on January 16, 2013.
Rio de Janeiro, Brazil	
Instituto Pereira, Passos Municipality of Rio de Janeiro, Brazil	An interview could not be arranged. Data obtained from secondary sources.
Chief Digital Officer, Rio de Janeiro	
Centro de Operações Rio (COR)	

Appendix 3: Interview Questionnaire

	Questions
1	"Smart Machines", Organization & Governance
	• What are the concepts and objectives of the "smart" applications for the city government?
	• How is the project considered "smart" compared to conventional methods?
	• Does the "smart" applications include characteristics of "smart machines", where functions are automated, employ algorithms and/or employ artificial intelligence?
	• In addition to meeting functional objectives, how, if any, has the organization benefitted from the 'smart' applications?
	• What challenges, both in function and organization, has the city faced?
	• Prior to implementation, did the "smart city" concept involve organization changes, e.g. restructuring of organizational structures and/or processes to effect the implementation?
	• Are there post-implementation organization changes, e.g. restructuring of organizational structures and/or processes, to harness the benefits of automation and the results of the 'smart' applications, i.e. 'informate'?
	• Does the "smart city" involve human input, e.g. where human traits of social and emotional intelligence, creativity, intuition, and improvisation lead to improved outcomes?
	• Are there other possible areas in the city where similar "smart" technologies may be applied?
2	Engaging partners: community & businesses
	• Does the "smart city" involve partnerships between the government, community, businesses and/or research institutions?
	• What is the partnership framework and what are their respective roles?
	• Who are the technology providers?
	• Are there key stakeholders, e.g. community groups, businesses, academic institutions, etc. which may contribute as important resources, but have been left out under the existing framework?
3	Learning, Relearning & Adapting
	• Does the "smart city" learn from other cities, e.g. through networks?
	• How, if any, does the city and its departments receive feedback or learn from its "smart" applications, e.g. through automated data analysis, regular reviews of policies & plans, etc.?
	• How, if any, has the city shown adaptation, i.e. through process of meeting short-term goals, contributed to or influenced its policies or plans for longer-term goals?
	• What performance metrics or frameworks related to these "smart" applications allow the city to chart its progress?
4	Business model & perspective
	• What were the city's key considerations prior to investing in the 'smart' applications?
	• How does the city perceive its return on investment (ROI) or expected payoffs?
	• What is the business model for the investment, e.g. how is the capital cost of the 'smart' applications funded and by whom, how are operational & maintenance costs funded, are there any cost-recovery services (e.g. sale of data) involved, etc.?
	• What is the ownership framework of the 'smart' applications, e.g. who owns the intellectual property of the 'smart' software, who owns the data, who has access to the data, etc.?