Defining the Middle Ground: A Comprehensive Approach to the Planning, Design and Implementation of Smart City Operating Systems

Christopher Grant Kirwan(✉)

Reignwood Innovation Technology Center, Beijing 100022, China
mustafa.kirwan@gmail.com

Abstract. As cities have become more sophisticated with the introduction of advanced information technology and with the widespread use of social media, there is a need to identify a middle ground (or connective mode) which links the operating systems of the city with its citizens. In order to develop a new viable model for Smart City operating systems, an in-depth understanding of key drivers of the city will be required. This process must simultaneously integrate both top-down and bottom-up data streams to allow operating systems to grow organically and sustainably, with the following goals: (1) Permit city leaders to make more informed decisions, (2) Create an open development environment that will encourage private enterprise to infuse capital, technology and innovative business solutions, (3) Allow citizens to participate in the operation and management of their communities. The primary objective of this paper is to define the required methodology to plan, design and implement appropriate solutions to City DNA through the use of an integrated "Middle Ground" approach.

Keywords: Smart Cities · City OS · Operating Systems · System Architecture · Urban Interface · City DNA · Collective Intelligence · Citizen Participation

1 Overview

1.1 Models of City Operating Systems

City operating systems (city OS) have been predominately developed as top-down management software systems built on legacy systems that typically are accessible to specialized software engineers or proprietary operators of the system. On the opposite side of the spectrum, there have been attempts to develop open-source operating systems representing a piecemeal assembly of fragmented software elements that have not provided a comprehensive integrated platform allowing seamless connectivity and operability between city management departments. Sophisticated Smart City platforms, including Microsoft's CityNext, now make possible comprehensive development environments and business platforms for third party developers to create specialized solutions.

P.L.P. Rau (Ed.): CCD 2015, Part I, LNCS 9180, pp. 316–327, 2015.
DOI: 10.1007/978-3-319-20907-4_29

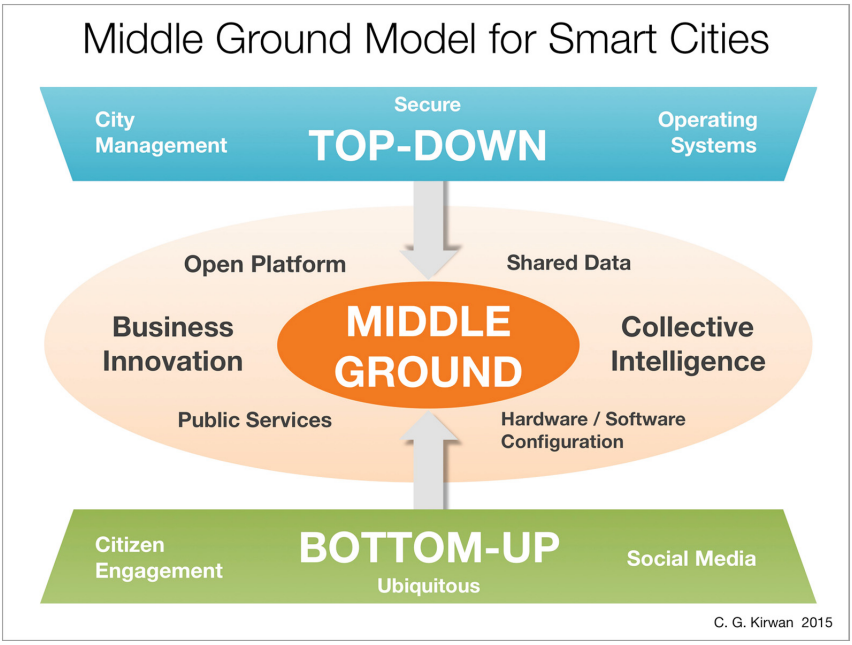

Fig. 1. Middle ground model

In many cases, the hesitation of city managers to adopt proprietary operating systems has been the perception that many large enterprises dominating the industry are locking in specific technologies that create a dependency on a singular solution rather than allowing an open-source approach. On the other hand, the open-source world has not fully been able to provide a solid, reliable platform for developers and is often overlooked by city managers for being too complicated. Therefore, the selection of smart city OS has remained a real issue for city leaders to decide on what is the best solution for managing their city and its citizens.

Figure 1 demonstrates a Middle Ground Model as described above; Top-Down refers to government, city management and the city operating systems; Middle Ground refers to a combination of business innovation and technology integration; Bottom-Up refers to the public realm, social media and citizens interface.

2 Operating System Design Factors

2.1 System Architecture

The typology of city operating systems require a holistic understanding of the unique physiology of each city in terms of the special combination of city governance structure, socio-economic environment and physical resources that assist city leaders in determining the best solution for the selection of their smart city OS. This will necessitate developing a comprehensive approach that allows the optimization of the

present infrastructure and operations while simultaneously planning for future growth and change in the system based on urban growth parameters. Therefore a careful study must be made to determine whether the proposed system should be centralized or decentralized in order to facilitate the management of various city operations, for example: transportation, security, utilities monitoring, etc. This structure is also highly determined by the structure of city governance and whether the city has moved towards privatization of city resources management.

2.2 Macro / Micro Scales

A major factor in the selection and design of city operating systems is the consideration of different scales of operations from macro systems including interconnected and overlapping functions to micro applications within the city. In order to accommodate these different scales, the planning and design of city OS must consider the city from both city management and operations while simultaneously designing for citizen participation and user experience. In my previous paper, *Urban Phenomenology: Incorporating Dynamic Frames of References in the Design of Urban OS*, I elaborate on the need for adaptable, holistic systems that allow the city OS to change frames of reference to best suit these differing requirements and points of view of the end user, from city managers, to citizens to visitors.

2.3 Technical Functions: Hardware / Software

Smart City OS are a combination of hardware and software solutions and must allow the interconnectivity of various systems to create a seamless flow of information management for the operation of city systems, technologies, software applications and equipment and in many cases this also includes the management and interface with the human labor force of cities. The Smart City industry has been typically divided between hardware and software providers although some of the major players like Siemens, Honeywell and others have developed both. As mentioned in the previous paragraph, it has been a dilemma for city leaders to decide the best platform combining both hardware and software since choosing a one-solution approach limits the development of open source, competitive solutions and locks city managers into purchasing from a single company that may potentially lead to a monopoly in the market. As a consequence city leaders must look for other options.

2.4 Collective Intelligence

As cities have become increasingly more complex to manage and as technology has become ubiquitous at multiple scales, the opportunity to incorporate the individual user as part of the city operating system has become a viable dimension to create more holistic approaches that combine both top-down and bottom-up solutions. In the 1970's and 80's in the US when crime was on the rise in many cities, and in many instances the police force was not adequate to monitor and protect all neighborhoods particularly

in poor districts or neighborhoods adjacent to blighted areas, the emergence of Neighborhood Watch became a viable model for self-protection. The Neighborhood Watch was made up of volunteers within the community who acted as responsible vigilantes to monitor neighborhood activities. This model became very popular across the country and was able, in many cases, to solve the issue of crime prevention and reduction. This bottom-up example illustrates how citizens can provide a valuable information network linking and augmenting city management. This citizen-centric approach has great potential today, especially with the ubiquitous nature of mobile media and the distribution of cameras and sensors throughout the city. The integration of human and computer systems, a collective intelligence, which I elaborate in the paper *Cybernetics Revisited: Towards a Collective Intelligence,* facilitates a more comprehensive solution for managing the city while allowing citizens to directly participate and influence their quality of life and at the same time providing a sense of involvement, pride and motivation in maintaining the city as a viable place to live and work.

2.5 Augmented Citizen Participation

By connecting citizens and designing solutions incorporating user experiences within city operating systems, cities can greatly benefit by the necessary human augmentation that is required to 'sense' beyond the technological limitations of current hardware and software. Of course in the future, artificial intelligence will begin to play the role of humans and human perception, however at the present stage of technology, the need for human participation within the city OS seems obvious and must be better utilized to improve both the psychological impact of citizens engagement as well as the need for real-time data collection and processing 'on the ground.' This is true for both existing city infrastructure as well as in the development of new and improved public spaces. In the paper *Ten Principles for Urban Regeneration Making Shanghai a Better City*, published by Urban Land Institute, states "The users of a place need to have a voice in its reuse. They too are experts - the most knowledgeable sources for what a site has in place and what it needs in its rejuvenation. They best know the site's history, which should inform its future. Both new forms of media and established practices can help residents' voices be heard. The intellectual capital and social infrastructure that drive contemporary cities should be integrated into urban regeneration. For example, technology can enable citizens to identify issues from potholes to cooking oil reuse."

2.6 The Role of Social Media

Social media has allowed users to create unique, personalized content while establishing broad networks for dissemination of community-based information. Much of this information has been for personal use and remains somewhat benign in terms of providing actual resourceful information to the direct management of cities. However, as big data has demonstrated, aggregating and filtering data can provide invaluable human behavioral intelligence. This information can be useful to predict individual and

collective system patterns and has a wide variety of applications. On the other hand, user generated content can be overwhelming and may clutter the overall flow of information within comprehensive, efficient systems. The primary goal of the middle ground approach must be to incorporate bottom-up information through improved applications that provide useful tools for citizens to interact with local government. In addition, it will be important to apply real-time data to inform top-down decision making in the planning and operation of our communities. The purpose of establishing a middle ground is not only to serve government needs to provide better public services, but to improve the quality of life by allowing citizens to participate in the living operating system of cities. Additionally, by linking individual users with city management in a more direct way, the potential for proprietary systems to dominate information could potentially be lessened by making the communication flow more accessible, public and transparent.

2.7 Role of Business Innovation / Private Sector

Another major challenge facing cities is the issue of funding and commercialization of operating systems. The limitation of city budgets to introduce new state-of-the-art operating systems is the real constraint for cities to upgrade and adopt new technology solutions that could make these cities 'perform' better. At the same time the proliferation of mobile media and of user generated content has not necessarily provided, in its own right, a viable economic solution to assist cities in investing and financing advanced smart city OS. The role of the private sector is critical to provide market driven momentum and entrepreneurial solutions to link the top-down governance of smart city OS while connecting and harnessing the power of bottom-up citizen participatory media. Arup, a leading smart city solutions provider, estimates that the global market for smart urban systems for transport, energy, healthcare, water and waste will amount to around $400 Billion per annum by 2020.

In China, city governments have spent major investments in constructing infrastructure and have provided the required 'hardware' for the city, but have now, in many cities, run out of funding to develop the software layers of these cities. In fact, the key issue in China is the lack of software solutions both in terms of human and computer software and services. The service industry is the next wave in China, which currently is slow to develop, leaving plenty of opportunity for development.

The recent highly successful initial public offering of Alibaba on the New York Stock Exchange has ignited the imagination and spirit of Chinese entrepreneurs to seek new business ideas within the Internet of Things and the tech sector. This market momentum may be the solution to drive technology and business innovation to create the middle ground, linking the massive population's supply of data with the requirements of cities to better operate by incorporating citizens participation within the design of smart city OS.

3 Case Studies

3.1 Comprehensive Approach to Smart Cities

In order to develop a comprehensive approach to the design, planning and implementation of smart city OS, the city must be understood from the macro socio-economic point of view. Through this point of view, a multi-layered system architecture can then be developed. The following case studies were selected to represent three major aspects of the system architecture required to develop smart city OS. The first case study represents a macro system view of the city that informs the key consideration that must be factored into the design and selection of the system architecture. The second case study represents an example of an open network platform that allows a more flexible system architecture adaptable to different city requirements and configurations. The third case study presents student research projects focused on user interface and how users of the system can be engaged and participate in smart city operations.

3.2 Case Study 1: City-wide System Strategy

In order to define and program the development of adaptive, intelligence strategies for nations, Harvard professor Michael E. Porter has been a pioneer in evaluating the competiveness of individual nations based on each nation's unique combination of natural resources, industries, labor force, etc. Based on the collection and analysis of this information, a comprehensive strategy is then proposed to optimize the economic and social objectives. Porter's Diamond Model framework from *Competitive Advantage of Nations* used to evaluate the competitiveness of nations can be applied at the city level. In Porter's model, *Factor Conditions* refer to the aspects of production such as skilled labor or infrastructure, necessary for city-to-city competition. *Firm Strategy, Structure and Rivalry* refers to, when applied to city settings, how cities are organized and managed. *Demand Conditions* refer to the cities citizens demand for goods and services. *Related and Supporting Industries* refer to the presence or absence of services that are unique to each city. A strategic plan can be developed for each city that informs the way its operating systems could be developed to best serve needs of the community and preserve its competitive advantages (Fig. 2).

3.3 Case Study 2: Open Platform

It has been argued that allowing propriety legacy systems as the basis of Smart City OS is detrimental to the development of adaptable and evolutionary operating platforms by constraining the use to specific operating systems and technology solutions. In the white paper *Framework for SMART City Deployment*, the author Paul Goff argues in favor of an open system approach as the underlining architecture of the smart city OS. "A legacy approach to the deployment of information technology systems within the city will be a constraint … Integration and convergence of physical and logical systems is the key to a successful SMART deployment."

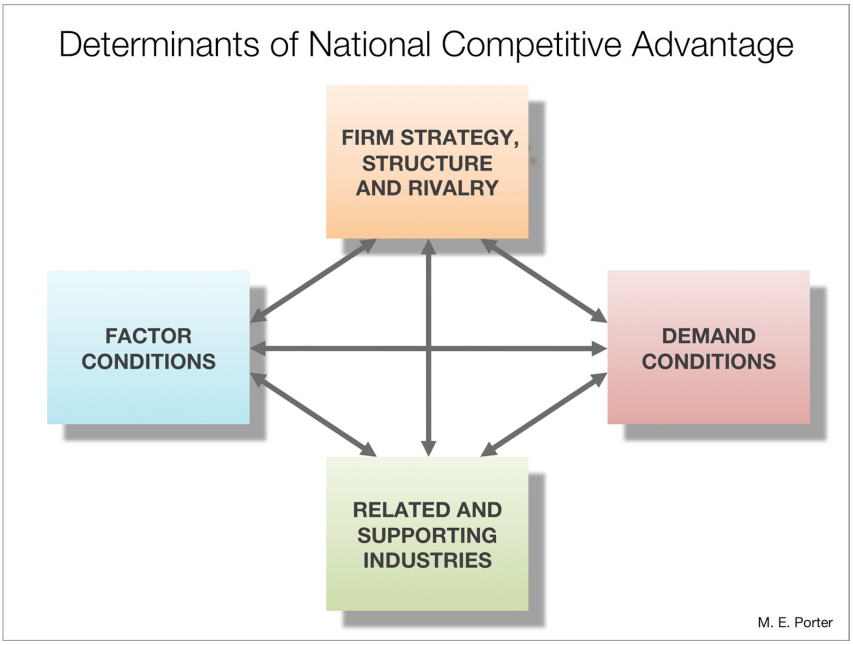

Fig. 2. Michel Porter's Diamond Model of competitive advantage

An example of a hybrid open operating system is presented in the paper *Civitas: The Smart City Middleware, from Sensors to Big Data*. The authors propose an open-middleware model that builds a flexible operating platform for multiple stakeholders to engage, share and build out the system in a more organic framework. The main feature of Civitas is a flexible cloud based IT platform that bridges city OS with third party enterprise developers and app developers with end users. The authors state "The ecosystem notion of a smart city is an abstraction that comprises the IT infrastructure deployed by governmental institutions all over the city, such as semaphores, traffic sensors, cameras, public wifi networks, etc. The Civitas platform counts on all these sources of information and actuation as its raw elements from which smart city operations can be articulated (Fig. 3)."

3.4 Case Study 3: Citizen Engagement / User Interface

Having lived and worked in China for the past six years, a period in history of Chinese development post 2008 Beijing Olympics that could be characterized as the 'Chinese Awakening,' has been an eye opening experience as a foreigner. The dichotomy arising from an accelerated opening to western influence, business and lifestyle, while maintaining China's restrained, reformist policy both to eliminate unwanted information proliferation from the west and anti-corruption measures internally within the present government, has created a back and forth situation between open and closed systems. As part of this amazing phenomenon has been the growth and proliferation of mobile

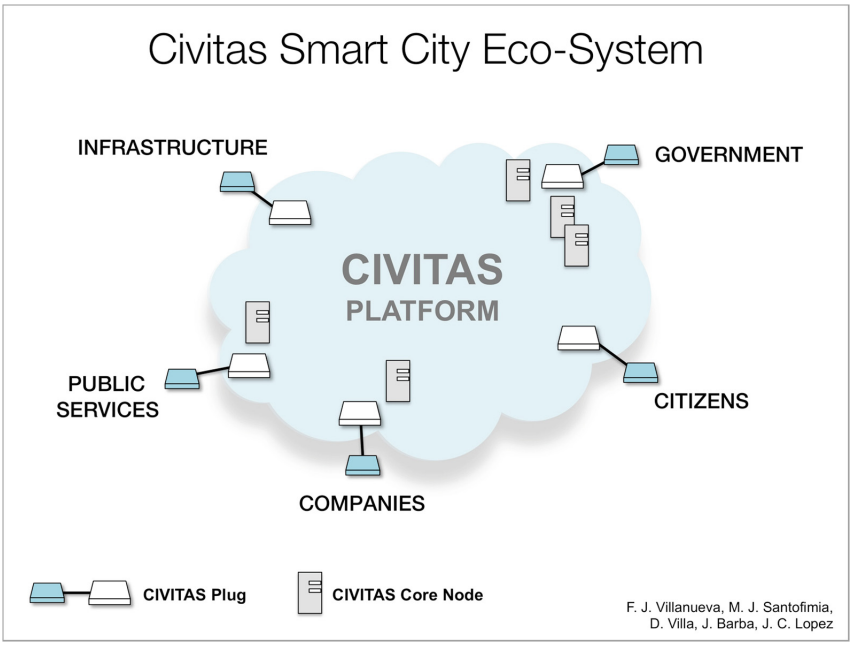

Fig. 3. Model of civitas platform

phones, social media and the new age of user interaction and participation, which would not inherently be considered a Chinese way. On the other hand this has led to numerous opportunities for Chinese citizens to influence how cities operate and to provide information that can be useful for leaders to better manage the vast developing cities that have become the symbol of China's growth and world prosperity.

As co-founder of *The Design Beijing Lab* and visiting faculty at Tsinghua University School of Art and Design, I had the opportunity, with lead faculty member Professor Fu Zhiyong, to conduct several design studios focused on research and design of citizen participation that bridge top-down and bottom-up solutions and seek to define the new concept of collective intelligence. In a studio class format, the following three projects are prototypes developed by student teams to explore the middle ground:

CityCare is a mobile app that allows citizens to post images with comments to a public BBS providing a shared platform accessible by city park managers to monitor and respond to public space maintenance. A more lyrical project, *Subscope* connects busy Beijing subways riders with city landmarks above-ground using a GPS-based function that geo-tags these specific landmarks allowing subway rider to create a collective database of personal narratives of these city landmarks. The *Smart Pedestrian Bridge* project considers how to make pedestrian bridges more effective, fun and interactive both as safe passages for pedestrians as well as to provide key traffic and other related information to automobiles and buses passing underneath. The *Smart Pedestrian Bridge* functions both as a physical bridge, as well as a digital bridge,

Fig. 4. Citycare application concept and interface

linking other Beijing bridges together into one integrated *infostructure* network. Each of these project examples seek to incorporate the design considerations discussed above including macro/micro scales, hardware/software solutions, and connect city management with citizen participation (Fig. 4).

4 The Proposed Solution / Conclusion

4.1 The Concept of City DNA

Building on Professor Michael Porter's approach, the opportunity to examine the unique combination of individual cities' advantages has led me to develop a comprehensive planning and design methodology termed City DNA to assist in defining a middle ground solution appropriate for each city. Like the concept of Brand DNA, City DNA evaluates brand identity, resources and competitive advantages among other key considerations for each city. Based on this information, the appropriate design framework is then established to develop a comprehensive system architecture. This architecture integrates a combination of government services, private enterprise solutions and end user applications that allow citizens to participate more directly in the overall smart city framework. The push-pull interaction allows the users to both access applications within the smart city framework while providing valuable user feedback data that can be used within the smart city OS to understand and improve the quality of life of the city. The data provider can be a range of entities from government agencies, corporations, and small businesses to individual users.

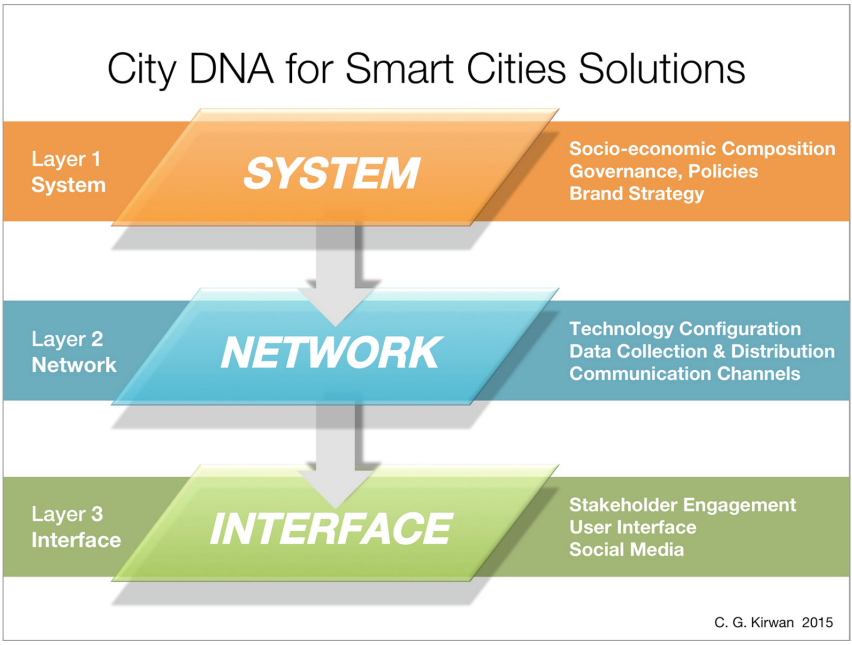

Fig. 5. City DNA for smart city solutions

4.2 Defining an Appropriate Solution for Each City

The City DNA framework has three layers System, Network and Interface that must be factored into each city DNA solution to create the unique operating system aligned with the brand and strategic positioning of the city. The importance of the brand dimension within the smart city OS design is required to provide a clear identity for each city to differentiate itself from other cities and to provide a solution tailored precisely to the unique combination of political, socio-economic and technological stage of development. Figure 5 identifies the three layers and their corresponding functions. System Layer refers to the macro level considerations that must be accounted for to select an appropriate operating system. Network Layer refers to the data collected and distributed in the cities. Interface Layer refers to the method that users interact with the system and provide data through the Interface.

4.3 Conclusion

In order to define and achieve a middle ground approach, a comprehensive understanding of the key drivers of each city is required to plan, design and implement a smart city OS appropriate for that particular community. The design must simultaneously factor in a combination of top-down and bottom-up considerations within the development of an open platform. This hybrid solution is necessary to drive the development of the smart city market that stimulates the economy of cities, creates new

opportunities for enterprises, allow governments to provide better services, improves quality of life and better engages citizens in participating in the management of cities. City DNA proposes a holistic methodology to develop a customized solution for each city by identifying the system, network and interface layers of such a smart city OS.

- Academic Research & Collaboration – Professor Dr. Fu Zhiyong, School of Art & Design and co-founder of Design Beijing Lab, Tsinghua University, Beijing, China.
- Design Beijing Lab, School of Art & Design Tsinghua University Student Projects: CityCare team members: Xu Lin, Wei Liu, Changjian Si, Peng Zhao, Jie Liu; Subscope team members: Junjie Yu; Smart Pedestrian Bridge team members: Shen Li, Luobin Wang, Jingli Zhu.
- Research Assistance – Nicholas Leong, Intern, Reignwood International Business Department.
- Editorial Support – Ernest E. Kirwan, AIA, retired architect / planner and faculty member, Harvard Graduate School of Design, Cambridge, Massachusetts, USA; Torkel Snellingen, MD, MPH, PhD, consultant, educator, Beijing, China.

Acknowledgements. I am pleased to recognize contributions to this paper made by the following colleagues:

References

1. Bianchi, N., Hartman, K.: What makes a city 'smart,' anyway?(2014). http://www.modeldmedia.com/features/smart-cities-meeting-of-the-minds-102114.aspx
2. BIS Research Paper No. 136 The Smart City Market: Opportunities for the UK. Research Paper, Department for Innovation and Skills (2013)
3. CityNext Enabling Real Impact for Better Cities with a People-First Approach. Technical report, Microsoft (2013)
4. Flood, R.L., Carson, E.: Dealing with Complexity: An Introduction to the Theory and Application of Systems Science. Springer, US (1993)
5. Goff, P.: Framework for Smart City Deployment TechiCity Project Report V1.0 (2013)
6. Intelligent / Smart Cities: Open Source Community. http://icos.urenio.org/about-icos/
7. International Making Cities Livable. http://www.livablecities.org/
8. Jacobson, C.: Ten Principles for Urban Regeneration: Making Shanghai a Better City. Technical report, Urban Land Institute (2014)
9. Kirwan, C., Travis, S.: Urban media: new complexities, new possibilities – a manifesto. In: Foth, M., Forlano, L., Satchell, C., Gibbs, M. (eds.) From Social Butterfly to Engaged Citizen, pp. 235–252. The MIT Press, Massachusetts (2011)
10. Kirwan, C.: Cybernetics revisited: toward a collective intelligence. In: Lima, M. (ed.) Visual Complexity Mapping Patterns of Information, pp. 252–254. Princeton Architectural Press, New York (2011)
11. Kirwan, C.: Urban phenomenology: incorporating dynamic frames of references in the design of urban OS. In: Rau, P. (ed.) Cross-Cultural Design Cultural Differences in Everyday Life, pp. 296–302. Springer, Heidelberg (2013)
12. Lee, Y.W., Rho, S.: U-City Portal for Smart Ubiquitous Middleware (2010)

13. National Neighborhood Watch - A Division of the National Sheriffs' Association. http://www.nnw.org/
14. Open Technology Institute. http://www.newamerica.org/oti/
15. Porter, M.: The competitive advantage of nations. Harv. Bus. Rev. **68**, 73–93 (1990)
16. Porter, M.: The Competitive Advantage of the Inner City. Harvard Business Review 73 (1995)
17. Pulido, A.T.: Open Smart Cities II: Open Source Big Data. Observatorio Nacional del Software de Fuentes Abiertas (2013)
18. Villanueva, F.J., Santofimia, M.J., Villa, D., Barba, J., Lopez, J.C.: Civitas: the smart city middleware, from sensors to big data. In: 2013 Seventh International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS), pp. 445-450. IEEE Press, Taichung (2013)
19. Wilson, M.: Far From a Shooting in Florida, an Increase in Block Watchers (2012). http://www.nytimes.com/2012/06/23/nyregion/neighborhood-watches-in-new-york-far-from-trayvon-martin-case.html?_r=1