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Article · January 2009

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Intelligent Cities: R&D offshoring, web 2.0 product development and globalization of innovation systems

N. Komninos[1] and E. Sefertzi[2]

Abstract: In the cities and regions of the twentieth first century a radical turn is taking place as information and communication technologies are converging with the innovation-led regional economies, innovative clusters and agglomerations. Intelligent cities are part of the orientation towards the creation of environments that improve our cognitive skills, our ability to learn, foresee, and innovate. The paper discusses the driving forces sustaining the rise of intelligent cities, such as the globalization of innovation clusters and networks, open innovation, and web-based collaborative environments. Then we look at the movements shaping them - local initiatives around the world, European Living Labs, and applications developed by large companies like IBM, MS and CISCO. The last part of the paper focuses on the planning challenges for building intelligent cities and interactive systems of innovation. We discuss the problem of integration among the physical, institutional and digital dimensions of intelligent cities and the 'bridges' that connect these three spatialities.

Key words: Intelligent cities; innovation systems; global innovation; collective intelligence; web 2.0

1. Introduction

Cities are changing. A new paradigm of city development and planning has arisen from the actual wave of globalization, emerging technologies, virtuality, and the collective intelligence of the web. Cities in Europe, USA, and Asia respond to these trends by a set of new strategies, namely intelligent city strategies. Well known cases are Living Labs in Europe, Singapore's iN 2015 strategy, Malaysia Multimedia Super Corridor, Florida's high tech corridor, and a series of innovation clusters / global hubs such as Arabianranta, Zaragoza Milla Digital, Seoul Digital Media City.

Intelligent cities highlight a key aspect of this new paradigm relating to the creation of environments that improve the cognitive and learning skills of the population and the knowledge and innovation capabilities of organizations located within them. Intelligent cities are territories in which the local system of innovation is enhanced by digital collaboration spaces, interactive tools, and embedded systems. Digital spaces, electronic devices, information systems and online services sustain a series of new urban functions related to knowledge creation, technology transfer, innovation, and global marketing and delivery. Virtual spaces and embedded systems are generating a wave of hybrid environments (global digital ecosystems, Living Labs, i-hubs, COINs, smart cities, e-gov, digital cities, U-communities, intelligent environments, etc.) which in turn amplify local creativities, networking, experimentation and innovation. The city gains innovation capability, which is translated into increased competitiveness, a better environment, more jobs and wealth.

2. Intelligent cities and globalization of innovation

For more than 20 years innovation has been a central driving force of urban and regional development. A rich literature corroborates this orientation; already the 6th Periodic Report on the social and economic situation and development of the regions of the European Union (1999) documented that the actual regional development of Europe is based on factors of knowledge, innovation, and geographical accessibility. Innovation-led or knowledge-based development of cities and regions has become the model which most cities and regions try to adopt and adapt it to their particular conditions. Central element in linking innovation and regional development is the concept of the regional system of innovation, which denotes the cooperation nexus among R&D,

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Paper presented at the Second Knowledge Cities Summit 2009, Shenzhen, China, 5-7 November 2009 (http://www.kcsummit2009.com/eng/index.html)

technology institutions, innovation funding, and production organizations located closely, as driving force of innovation and regional development.

However, recent trends reveal a profound transformation of regional systems of innovation towards more outward and global profiles. Several factors contribute to this change: a new geographical mobility of R&D, R&D offshoring, new supply chain architectures shaped by flagship networks of multinational companies, rise of global clusters of excellence, people-led product innovation, web 2.0 and participatory product development. Altogether these changes create a new spatiality of innovation systems, shaped by global innovation networks and digital collaboration networks, and reveal a new way of innovation, more global, open, and participatory. 'Intelligent cities" is a planning paradigm which corresponds to this type of innovation spatiality shaped by global innovation networks and web-based collaboration.

The globalization of innovation networks is a contemporary trend deeply influencing local innovation clusters and regional systems of innovation. Decentralizing business units and operations to every corner of the world has become routine practice, but now companies are also redistributing their product innovation, even basic and applied research, across global R&D networks (Ernst 2006; United Nations 2005). Cisco has R&D facilities in Bangalore; Toyota in Thailand; Nokia operates nine satellite design studios located within targeted nations like India (Bangalore), China (Beijing), Brazil, where researchers and designers work to customize products to each market (BusinessWeek 2007). The UNCTAD survey on the internationalization of R&D shows that China has become the most attractive destination for non-equity R&D collaboration (UNCTAD 2005). The majority of the new R&D centers that multinational companies plan to open during the next years are to be located in India and China. A recent survey conducted by the Economist Intelligent Unit (2004) documents the many reasons that drive the actual relocation of R&D. Reduced R&D costs and the ability to take advantage of local pools of skilled labor are among the most important delocalization factors. However, new factors have also appeared alongside the classical factors of FDI attraction (proximity to local markets and bypass of tariff barriers): tapping into pools of local know-how; taking advantage of local creativities; avoiding relocation expenses; and shrinking of R&D budgets.

The global decentralization of R&D and innovation has a direct impact on local and innovation clusters and regional innovation systems as well. It is well documented that innovation activities tend to cluster. In Europe, for instance, R&D laboratories and companies active in R&D are concentrated to a great extent in a series of urban islands of innovation and innovative regions in north-west Europe and Scandinavia. This spatial polarization of innovation is explained by the horizontal and vertical knowledge interaction within the clusters, local knowledge spillovers, and the 'embedded tacit knowledge" thesis. Recent evidence however maintains that international relationships and global knowledge flows are crucial sources of creativity and innovativeness within local innovation clusters. Successful clusters are building and managing resources from around the globe (Bathelt et al. 2004; Owen-Smith and Powell 2004). There is growing evidence that even in the most innovative clusters an important proportion of their knowledge and customer bases are not local (Gertler and Wolfe 2005). Local clusters and innovative cities are going global to take advantage of external resources (supply chains and knowledge inputs), market opportunities (suppliers and customers), and the attractiveness of global funds and investments (Uhlmann 2008). In developing countries, innovation offshoring tends also to cluster. Offshoring takes place in a limited number of cities and regions in India, China, Malaysia, and in global city-regions like Singapore and Hong-Kong, giving birth to agglomerations of high-tech activities and innovative clusters.

Confronting these trends of intense R&D mobility and innovation globalization, many communities and cities have launched 'intelligent city' strategies. Public authorities in Singapore, Taipei (China), Spokane (US), Seoul and Songdo (S. Korea), Cyberjaya and Putrajaya (Malaysia), in many cities of Europe, and in 'smart communities' in the US have implemented plans to make their cities more 'intelligent', 'open', 'global' and 'innovative'. In the planning discourse of these cases, the connection between innovation, broadband, and globalization is more than evident (IDA 2009, Bunnell 2002).

3. Movements shaping intelligent cities

Fragments of intelligent cities are emerging all over the world, but still we are very far from the creation of amazing intelligent environments that open minds and transform radically human skills and mental capabilities. This is a weakness both of technology in the field of intelligent environments and of integration of technologies with innovation institutions and city activities. However, some major shaping movements have already appeared.

Local initiatives – The ICF awards: An extremely valuable source of current applications and local experimentations in the field is to be found in the Intelligent Community Forum and the cities selected by ICF since 2001 as top intelligent cities (ICF 2009). Forty cities and regions appear on this list covering a variety of sizes and roles: small cities like Pirai with 23 thousand people to multimillion cities like Tianjin with a population of 11 million; global metropolis like New York and small rural communities like Bario, Malaysia; industrial cities and city suburbs (Table 1). Among them, awards for Top Intelligent Communities were received by LaGrange, US (2000); New York, US (2001); Calgary, Canada (2002); Glasgow, UK (2004) Mitaka, Japan (2005); Taipei, Taiwan (2006), Waterloo, Ontario, Canada (2007), Gagnam District-Seoul, S. Korea (2008), and Stockholm, Sweden (2009).

Table 1: Top-seven intelligent communities selected by the ICF 2001-2009

	Asia – Australia (11)	Americas (18)	Europe (9)
2001	-Bario, Malaysia -Singapore	-LaGrange, Georgia, US -Nevada, Missouri, US -New York, US	-Ennis, Ireland -Sunderland, UK
2002	-Bangalore, India -Seoul, S. Korea	-Calgary, Alberta, CA -Florida, high tech corridor, US	
2003-04	-Taipei, Taiwan -Victoria, Australia -Yokosuka, Japan	-Spokane, Washington, US -Western Valley, N. Scotia, CA	-Glasgow, UK
2005	-Mitaka, Japan -Tianjin, China	-Pirai, Brazil -Toronto, Ontario, CA	-Issy-les-Moulineux, France
2006	-Gagnam District Seoul -Ichikawa, Japan	-Cleveland, Ohio, US -Waterloo, Ontario, CA	-Manchester, UK
2007		-Ottawa-Gatineau, Ontario, CA	-Dundee, Scotland, UK -Tallinn, Estonia
2008		-Fredericton, New Brunswick, CA -Northeast Ohio, US -Westchester, New York, US -Winston-Salem, N. Carolina, US	
2009		-Bristol, Virginia, US -Moncton, New Brunswick, CA	-Eindhoven, Netherlands -Stockholm, Sweden

* Each community appears one time only, the year of its first selection
Source: http://www.intelligentcommunity.org

These cities were characterized as 'intelligent communities' with respect to five criteria of excellence in information and communication technology, knowledge and innovation: *Broadband infrastructure*, which evaluates the local capacity for digital communication. *Knowledge workforce*, which measures the capacity of the population for qualified work in knowledge-intensive activities. *Innovation*, which assesses how far communities have gone in creating an innovation-friendly environment that attracts creative people and creative businesses. *Digital democracy*, which assesses the government and private sector programs to overcome the digital divide. *Marketing*, this assesses the attractiveness of a community and its competitive offerings with respect to other cities and regions.

In the cities which received ICF prizes, two strategies can be discerned. The first is a purely IT strategy focused on information technology with core elements 'broadband', 'IT training', and 'e-services'. Characteristic examples are Singapore, Seoul and Taipei. The second is a strategy focused on knowledge-based development and the local innovation economy and combines new economy structures (clusters, high-tech districts, innovation centers, venture capital funds) with broadband infrastructure and e-services. Characteristic examples here are New York, Florida, Glasgow, Yokosuka, Waterloo, and Stockholm.

EU Living Labs: Another major initiative in promoting the integration of localities, ICTs, and innovation is the EU 'Living Labs' movement. LLs started as a European platform for collaboration and opening innovative

markets in the field of mobile applications and technologies to European citizens, companies, and researchers. It is targeted at cities and regions advancing their telecom infrastructure and digital services in view of becoming significant transaction points for global flows of goods, services, people and ideas. Infrastructures are improved; public policies are adapted to firm-specific assets; clusters of competencies are maintained and advanced by applied research and experimental development, education and training. The entire urban environment becomes a 'living laboratory' for prototyping and testing new technology application and new methods of generating and fostering innovation processes in real time.

The definition of Living Lab given by the European Network of Living Labs (ENOLL) is that 'a Living Lab is an open innovation environment in real-life settings in which user-driven innovation is the co-creation process for new services, products and societal infrastructures. Living Labs encompass societal and technological dimensions simultaneously in a business-citizens-government-academia partnership' (Bergvall-Kåreborn and Ståhlbröst 2009). A Living Lab can be a city area in which operates a full-scale urban laboratory and proving ground for inventing, prototyping and marketing new technology applications; it may include interactive testing, but is managed as an innovation environment well beyond the test bed functions. As a city-based innovation environment the Living Lab can take advantage of the pools of creative talent, the affluence of socio-cultural diversity, and the unpredictability of inventiveness and imagination in the urban setting (Komninos 2008).

Ongoing Living Labs initiatives can be found in most major cities of Europe. ENoLL is now based on a total of 129 Living Labs, including 10 affiliated Living Labs from non European Countries. In these places, a real-life open innovation environment has been set in which user-driven innovation takes place and co-creation processes in many different sectors of economic activity, not only mobile devices and ICTs.

Big three*:* Large IT and telecommunication companies such as CISCO, IBM, MS, have also developed solutions for intelligent cities. In February 2009, CISCO, launched the global *Intelligent Urbanization* initiative from Bangalore and signed a MoU with the local government to develop a roadmap for an intelligent and sustainable Bangalore City. The global *Intelligent Urbanization* initiative was designed to help cities around the world using the network as the fourth utility for integrated city management, better quality of life for citizens, and economic development. Bringing together a broad portfolio of products, services, partners and solutions across CISCO, the initiative is initially focused on intelligent, sustainable solutions for public safety and security, transportation, buildings, energy, health care and education. As an example of how technology can be used to improve security operations, Cisco proposed its own internal Security Operations Centre. Real-time security monitoring and alerts, video surveillance tools, acoustic sensors, card-readers with biometric recognition, automatic alerts and security activation systems were the highlights of this environment.

Microsoft is working with Coventry University and Birmingham City Council to establish Birmingham as the first UK 'Intelligent City' able to showcase new and innovative applications. The *Intelligent City Proof of Concept* is about an interoperable technology platform focusing on transport. The objectives include demonstrating the intelligent city vision for Birmingham and creating a service layer platform integrated with existing data / services, managing journeys across devices and modes of transport, empowering individuals to make more informed, smarter choices, and describing the impact on travel patterns, and economic and environmental issues.

IBM announced its *SmarterCities* program as part of the company's initiative for an *Intelligent Planet*. The program was created to stimulate economic growth and quality of life in cities and metropolitan areas with the activation of new approaches of thinking and acting in the urban ecosystem. Interconnected and instrumented smart technologies offer a real-time integrated view of complex city systems, enabling administrators to monitor operations, improve performance and respond to the needs of their jurisdictions each day. IBM's initiative focuses on seven areas, education, health, safety, transport, water management, energy, and public governance in each of which the company described a series of best practices, strategies, technologies and applications (IBM 2009). The approach is comprehensive, as the problems are not addressed only in terms of technology, but management practices and institutional arrangements are also taken into consideration.

4. Planning challenges

The above movements bring on the surface a number of planning challenges linked to the multi-dimensional spatiality and architecture of intelligent cities, which is simultaneously social, physical, institutional, and digital.

Integration: Intelligent cities are organized as multi-layer territorial systems of innovation, bringing together knowledge-intensive activities, innovation institutions, and digital communication spaces. These layers reflect both the different dimensions of intelligence (human, collective, artificial) and the deployment of innovation on physical, institutional and digital spaces.

- The first layer includes the city's knowledge-intensive activities in manufacturing and services that are usually organized into clusters. The population of the city, knowledge workers, and innovative companies are the fundamental elements upon which intelligent cities are constructed. Proximity in physical space is important, integrating enterprises, production units, and service providers into a coherent innovation system. Critical factor at this level is the intellectual capital of the city population.
- The second layer includes institutional mechanisms for knowledge creation and social co-operation in technology and innovation. Characteristic examples are institutions enhancing R&D, strategic intelligence, venture capital financing, technology transfer, and collaborative new product development. These are mechanisms that promote cooperation within the clusters comprising the city, between different clusters in the city, and between innovation processes taking place on physical and digital space. Critical factors at this level are institutional thickness and collective intelligence of the community.
- The third layer includes digital networks and e-services that enable online cooperation. These tangible and intangible infrastructures create virtual innovation environments based on multimedia tools and interactive technologies, which facilitate different innovation processes from market and technology intelligence to collaborative new product development and process innovation based on transaction-saving technologies. Critical factor at this level is content management, information automation, intelligent agents, virtual networking and web 2.0 technologies.

A major challenge for building intelligent cities is integration among the above three layers and the making of 'bridges' that connect their physical, institutional, and digital spatiality. Analysis of intelligent places shows that most 'bridges' are organizational and institutional in nature and highly dependent on the digital technologies implemented.

Technology: Computer Aided Design (CAD) and Geographical Information Systems (GIS) are major technologies enabling a digital management of urban space. Intelligent cities, however, rely on a different set of technologies, web-based applications, virtual collaboration tools, and u-communities (Anttiroiko, 2009). Main difference of web-based tools with respect to CAD and GIS are that they help creating digital operational spatialities instead of representing digitally physical space. Furthermore, instead of two technologies we are dealing with an ocean of applications and virtual tools. On the website of URENIO we created a collection of representative collaborative tools for intelligent cities (http://www.urenio.org/digital-collaboration-tools/). These tools are organized in four categories (content management, technology transfer, collaborative product development, and digital marketing) and highlight how digital collaboration may contribute to main innovation processes. Web 2.0 offered additional means in mobilizing and organizing collective intelligence with application like Innocentive, iBridge, CrowdSpirit, IdeaScale, Peer-to-Patent, and other.

The dominant software stacks used in such collaborative environments are open source. The integrated, optimized, open-source Apache, MySQL, PHP/Perl/Python (AMP) stack seems to be the preferred platform for building and deploying new Web applications and services.

Today cloud computing makes a new step of efficiency and economy to this environment, delivering IT resources on demand and opening up new business models and market opportunities. In some ways cloud computing is a metaphor for Internet-based services and the increasing movement of virtual computing and hosting data resources onto the Web. It abstracts the software application platform from the underlying hardware infrastructure, freeing developers and users from the need to poses hardware. In cloud computing, the user's data and software execution are in the cloud (the Internet) and the network becomes the computer, while the use of resources follows the model a utility pricing (Sun 2009). Cloud computing by delivering higher efficiency, massive scalability, and faster, easier software development, with lower costs opens new windows for the massive involvement of people in the creation of digital spaces and e-services, and further development of intelligent cities as collaborative environments.

Sectoral and district-based strategies: In a previous paper (Komninos 2009) we argued that three types of strategies predominate in the making of intelligent cities. By developing sector-focused, cluster-based, or large scale intelligent city strategies, administrations set in motion mechanisms that enhance substantially the innovation system in their territory. Working recently on the project *Intelligent Thessaloniki* we found that e-

services and IT applications for collaboration and innovation vary considerably from one city district to another. The project concerned the design of broadband networks and digital services in six districts of the city of Thessaloniki: the port area, the commercial city centre, the university campus, the Technopolis IT business park, the museum of science and technology, and the airport. The objective was to enhance the innovation potential of these districts through the deployment of digital services and collaborative spaces. In each district we tried connecting its particular activities with innovation support processes and online collaborative spaces and tools. The difference of applications from one district to another is impressive, which advocates in favor of a sectoral approach and strategy enabling economies of scope and transferability of practices and applications.

Measuring: Defining metrics in the field of intelligent cities is driven by two principles: (1) to compare localities between themselves and learn from the best, and (2) to understand the internal dynamics of intelligent cities, define weaknesses, and recognize the effort needed to overcome them. Two methodologies predominate in these attempts: benchmarking and modeling. Comparing localities that have implemented intelligent cities strategies is the scope of territorial benchmarking. We may benchmark any type of organization, institution or geographical entity, provided that we have comparative data from other similar entities. Modeling is more advanced methodology and requires deeper analysis, testing, and understanding. It is mainly about the relationships of the variables that characterize intelligent cities, analyzing how different structuring aspects of the city interrelate; and to what extent performance variables of innovation are dependent on the structuring variables of human skills, institutions, and digital infrastructure. Both, benchmarking and modeling are based on the use of quantitative indicators, which have to cover the entire field of intelligent cities activities and functions. In Table 2 we have selected around 40 indicators organized into four blocks corresponding to fundamental building blocks of intelligent cities.

Table 2: Forty indicators for capturing intelligent cities performance

Education and skills of the population	Knowledge and innovation institutions	Digital infrastructure and e-services	Innovation performance
1. Population with tertiary-level education (% of 25-64 years age class)	1. Number of university students (% of total population)	1. City area covered by cable networks (% of total area)	1. EPO patent applications (per million of population)
2. Participation in life-long learning (% of 25-64 years age class)	2. Number of university staff (per million of population)	2. City area covered by Wi-Fi networks (% of total area)	2. New trade marks (per million of population)
3. New S&E graduates (% of 20-29 years age class)	3. Total R&D expenditure (% of GDP)	3. City area covered by xDSL networks (% of total area)	3. Innovative enterprises-manufacturing (% of all manufacturing enterprises)
4. Researchers in industry and services (% of total workforce)	4. Public R&D expenditure (GERD as % of GDP)	4. Computers (per million of population)	4. Innovative enterprises-services (% of all services enterprises)
5. Researchers in the public sector (% of total researchers)	5. Business R&D expenditure (BERD as % of GDP)	5. Internet connections (% of population)	5. Enterprises having internal R&D department (% of all enterprises)
6. Researchers in the private sector (% of total researchers)	6. Business spending for licensing (% of turnover)	6. Broadband connections (% of population)	6. Sales of new-to-market products (% of turnover)
7. Employment of tertiary-level graduates (% of total employment)	7. Number of incubators (per million of population)	7. Users of e-gov services (% of population)	7. Sales of new-to-firm not new-to-market products (% of turnover)
8. Employment in medium and high-tech manufacturing (% of total workforce)	8. Number of S&T Parks (per million of population)	8. City enterprises owning a website (% of total enterprises)	8. New companies creation (% of total enterprises)
9. Employment in high-tech services (% of total workforce)	9. Number of Technology Transfer and Innovation Centers (per million of population)	9. City enterprises involved in B2B or B2C (% of total enterprises)	9. Exports high-tech products (% of total exports)
10. Creative class (% of employment in creative industries)	10. Venture capital funding (% of total business funding)	10. Digital services providers (% of ICT companies)	10. Exports high-tech services (% total exports)

Out of these metrics four axis of intelligent city development can be defined. Three of them deal with input factors (skills, knowledge institutions, digital spaces), while the fourth measures outputs (innovation). A 4-dimensions radar chart thus may be defined measuring the progress made in each of the four fundamental

dimensions of an intelligent city. We should, however, keep in mind that intelligent city strategies successfully followed within a particular region may not necessarily generate the relevant results if copied to another region.

Future directions: Today intelligent cities offer an attractive prospect, a strategy and a vision for the future, rather than an actuality that has been realized. Key issue in making such environments is to understand and manage the linkages between the physical, institutional and digital aspects of innovation and how these interconnections activate knowledge functions, release creativities and transform knowledge into new products. Intelligent cities can achieve more global and interactive systems of innovation enabling, through the digital interaction, an extension of innovation collaboration networks and the participation of users. These are two novel elements (global innovation networks / user participation to innovation) that broadband communication and digital collaborative spaces bring into local / regional systems of innovation.

However, the precise way that digital collaboration enables the participation of overseas researchers, suppliers, innovators, customers, and end-users to innovation processes has to be defined with respect to the functional differentiation and complexity of the city. Different forms of IT applications, virtual spaces and novel e-services have to be defined in different city districts of industry, technology, university, CBD, shopping, port, and airport areas. Intelligent cities are emerging as dynamic re-arrangement of networks, nodes and clusters. The creation of intelligent innovation ecosystems is a major challenge for the future.

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