

New Services Design for Smart Cities: A Planning Roadmap for User-Driven Innovation

Nicos Komninos
URENIO Research
Aristotle University of Thessaloniki
PO 491, 54124
Thessaloniki, Greece
+30 2310 995581
komninos@urenio.org

Panagiotis Tsarchopoulos
URENIO Research
Aristotle University of Thessaloniki
PO 491, 54124
Thessaloniki, Greece
+30 2310 489304
patsar@auth.gr

Christina Kakderi
URENIO Research
Aristotle University of Thessaloniki
PO 491, 54124
Thessaloniki, Greece
+30 2310 995583
christina@urenio.org

ABSTRACT

As city authorities are becoming increasingly aware of the concepts 'intelligent city' and 'smart city' they undertake initiatives for designing new e-services that address challenges of development and sustainability more efficiently. However, the existing literature primarily focuses on application development, while the whole city planning process and involvement of citizens and end-users in the design and implementation of e-services for urban renewal is still a largely unknown field. After a literature review on smart city strategies and planning as well as a description of a pilot case for the creation of a smart city district, which was implemented in the framework of the PEOPLE project, the present paper concludes with a holistic approach for planning smart cities and designing e-services collaboratively in the form of a strategic planning roadmap.

Categories and Subject Descriptors

K.6.0 [Management of Computing and Information Systems]: Project and People Management – *general*.

General Terms

Management and Design

Keywords

Intelligent cities; smart cities; open innovation; web applications; strategic planning; roadmap

1. INTRODUCTION

Cities all over the world undertake 'intelligent city' and 'smart city' initiatives aiming to achieve a more effective management of infrastructures and resources and address challenges of development, sustainability, and inclusion. In these endeavors, city managers and planners are more and more concerned with methodological and procedural issues, such as how to achieve spatial intelligence; how a city can become more effective in solving urban problems; how it can deploy e-services and become more competitive, sustainable and inclusive.

This paper focuses on the methodologies for the design of e-services for smart cities, taking into account all the complexity of such environments and mainly the involvement of citizens and users in successive innovation cycles.

Over the last decades there was a plethora of studies and references related to the development of smart or intelligent cities. Some studies just refer to the use of ICTs and/or the fragmented development of digital applications, while others describe plans that better correspond to efforts of image building and a proof of status in the global competition of cities. There are also strategies that directly copy best practices; they do not meet the needs of the community they are addressing, neither the requirements of the specific urban context in which they are applied. Moreover, there are cases which deploy 'top-down' procedures and do not involve citizens, stakeholders, or other key individuals of the community in order to benefit from collaborative efforts and collective intelligence. The variety of such strategies reflects the respective variety of underlying concepts behind the terms 'intelligent city' and 'smart city' [1, 2, 3].

However, building an intelligent city is an accomplishment that demands a strategic approach and the integration of processes that are critical throughout the journey of digital transformation and collective intelligence building. These processes include, among others, the contribution of citizens, users, and consumers to the development of solutions in all aspects of the city life and activity, the

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

WiMobCity14, August 11, 2014, Philadelphia, PA, USA.
Copyright © 2014 ACM 978-1-4503-3036-7/14/08...\$15.00.
<http://dx.doi.org/10.1145/2633661.2633664>

knowledge distribution into a community, and the interconnection of devices, applications and e-services. Consequently, it is not only the variations on the concept of an intelligent / smart city strategy but also the complexity of achieving such a task and the vast array of elements that this task should integrate, that makes it difficult to perform planning for intelligent cities. Moreover, a collaborative and distributed intelligence environment in smart cities is not something that evolves naturally or happens gradually but needs careful orchestration and integration of multiple human and technological resources [4]. The challenge of wide collaboration and greater efficiency in addition to the integration of digital technologies into city's infrastructure renders traditional city planning methods inadequate.

To date, the relevant state-of-the-art literature focuses mostly on the architecture and the different components of intelligent cities while planning, as a methodology guide of goal setting and achievement, is still a largely unknown field. This means that there is a need for a planning roadmap that integrates the physical, institutional, and digital dimensions of cities, activates communities and stakeholders, ensures their involvement from the very early stages, develops custom solutions that address efficiently both existing and emerging urban problems, and offers higher spatial intelligence through a process of open innovation and web-based collaboration.

This paper focuses on this problem by proposing a well-defined methodology for planning intelligent cities or city districts in the form of a roadmap. The aim of the roadmap is to ensure (i) the targeting of smart city environments, applications and e-services on the real problems and challenges of cities, (ii) the actualization of a community's collective intelligence through bottom-up participative processes engaging stakeholders, end-users, citizens, developers, and organizations in the selection, design, and development of solutions and e-services, and (iii) the interconnection of smart environments and e-services with the physical space, institutions, infrastructures, and the functioning of cities.

The paper continues with a short review of intelligent city strategies and planning and the identification of a number of critical elements throughout a city's process of becoming 'intelligent' or 'smart'. Section three presents a case study of designing and implementing a smart commercial district in the city of Themi, in the Greater Area of Thessaloniki, Greece (<http://smartcity.themi.gov.gr/>). This case study, in addition to a few others that have been realized within the framework of the EU funded project PEOPLE, helps to identify a way for integrating critical elements of smart city planning in a methodology path. A problem-oriented approach is adopted as the concept of intelligence is usually linked to the ability of solving problems and accomplishing objectives. This approach, in the form of a planning roadmap, is presented in section four.

2. STRATEGIC PLANNING FOR SMART CITIES

Intelligent or smart city planning and strategy approaches can be found in different context and development efforts, applied at different scales and domains, such as sector-based strategies, district-based strategies, agglomeration of multiple cores and sectors, and holistic/cohesion strategies [5]. They refer to cities at different stages of development, i.e., existing in transformation or new cities under development. They constitute formal strategies and programs funded by government agencies or emergent initiatives created by individuals, community groups, stakeholders, and citizens [6].

Identifying and understanding successful strategies and key elements of 'intelligent' or 'smart' cities can be the first step towards the definition of a holistic planning methodology. As it is explained below, there is no generally accepted path for planners and policy makers; in most cases, strategies constitute custom made solutions targeted to specific needs of the area reflecting political and/or community priorities. However, the risk of confusing collaborative efforts, which add value and find solutions to urban problems within a community framework of reference, with initiatives and policies that solely promote the use of ICTs and smart technologies in the urban space, justifies the need for a more detailed review of planning practices.

Top-down planning

A large number of contributions in the relevant literature refers to cities that are being built from scratch such as Songdo (Korea), Masdar (UAE), Living PlanIT Valley (Portugal), and Neapolis (Cyprus). Such cities have the luxury of incorporating a vision for intelligence since their inception and early construction. In this process, top-down planning is applied without citizen involvement throughout the design and implementation phases. Here, the methodology adopted is often linked to a city's development lifecycle combined with efforts to optimize city operations through the integration of technology solutions. Neapolis smart eco-city in Cyprus, for instance, has followed a number of development stages that are very much like the steps taken in town planning: conception, analysis, planning and design, implementation, launch and operation, monitoring and control [7]. In addition, as technological infrastructure is a basic component in the design of new cities, these cities also provide a more fertile ground for the use of platforms, e-services, and smart environments in many different domains. The solution developed by Living PlanIT in Portugal, for example, is based on an urban operating system that has been built upon Cisco infrastructure and Microsoft Cloud platforms. This platform enables a four-layer connected structure that consists of (i) key challenges, (ii) people and processes, (iii) application capabilities, and (iv) technology [8]. Due to

the great concern of developers / planners towards sustainability, new business models were designed to respond to key trends and market opportunities, as in the case of New Songdo or PlanIT.

Bottom-up regeneration

However, existing cities or city districts with complex urban problems and multiple conflicting forces are far more demanding in terms of design and strategy implementation. Addressing the challenges of becoming sustainable, attractive and competitive or overcoming persistent problems of existing cities is not like painting on an empty canvas.

Cities such as Amsterdam, Manchester, Stockholm and Helsinki [9, 10] have taken the right steps towards becoming more intelligent through the careful selection and successive implementation of projects and initiatives, each one offering added value to a common objective. In these cases, the involvement of stakeholders goes hand in hand with the existence and operation of a smart city office (e.g. Smart City platform in Amsterdam, Forum Virium in Helsinki) which undertakes the task of communicating a vision and establishing fertile partnerships [2]. The challenge here is to identify the best possible way of aligning such initiatives with cohesion policy objectives and to activate local players (communities, stakeholders, etc.). Additionally, particular focus is given to applications and initiatives that are based on social innovation and community infrastructure. Despite these general directions, in the list of cases of intelligent cities around the world there are very few examples of explicit methodologies that a city should follow.

Planning roadmaps

Helpful and more integrated insights, regarding intelligent city strategic planning, can be found in reports of global technology vendors and infrastructure providers such as IBM, Cisco, HP, Microsoft, Oracle and Accenture. These companies offer programs dedicated to developing and providing technology solutions for digital strategies that refer to and enhance all aspects of cities everyday life and government.

A general approach is proposed by IDC Government Insights, which argues that there are three significant steps in order to build a smart city: (i) an explicit smart city mission statement with broad goals, aiming to elevate the level of the citizens' quality of life and promote sustainable development, (ii) specific city domains with domain-focused goals, such as the use of different smart technologies and applications to deal with different problems within the urban context, and (iii) a smart city investment strategy by determining priority areas for smart solutions [11].

Similarly, Accenture [4] considers that although there is no one best way to build a smart city, before planning the

strategy and implementing the program, it is necessary to assess the city's starting point, on the basis of its unique geographic location, economic and political situation, in order to weigh the costs, impacts, and trade-offs of each planning scenario. The company provides also five principles that are significant to the whole endeavor without, though, mentioning the order in which they should be pursued. The principles are: (i) encourage and develop new forms of leadership and governance structures, (ii) align and engage all relevant stakeholders, (iii) ensure the capabilities required to drive an open, intelligent infrastructure, (iv) extend the manager's capabilities in programming management and delivery and (v) create financial models able to face the challenges and exploit the opportunities ahead.

On the contrary, the IBM strategy proposal [12] includes three smart city building processes: *instrumentation*, which enables cities to gather more high-quality data using utility meters and sensors, *interconnection*, which creates links among data, systems and people, and *intelligence* in the form of computing models and new algorithms, enabling cities to generate predictive insights for informed decision making and action [13]. Intelligence is achieved through three layers: L1-strategic insight, in order to create a unique, engaging and unifying vision, L2-integration and collaboration, and L3-smarter city solutions and services addressing problems of the city [12].

Other contributions on intelligent city strategic planning highlight the importance of formulating an integrated vision with measurable objectives, of incorporating managerial and organizational strategies, smart computing technologies and infrastructures, the participation of people and communities, political and institutional readiness [2, 3].

Milestones of planning and services design

Based on the above observations, a well-defined and generally applicable methodology should be based on critical elements of strategic thinking, social context, technology foresight, setting objectives, and governance. It should integrate these critical planning elements, leading to a holistic approach of planning for intelligent cities. A comprehensive process, in the sense of strategic planning roadmap designed to transform a city or city district into an intelligent one, should incorporate the following elements:

- *Context and problem definition*: Identifying and prioritizing problems is a significant component of every strategy design. A strategy should bring clarity and define the vision based on the needs and priorities of the city. A common way to start is by analyzing the city's starting point and its particular characteristics (geographical, economic, sectorial and political) according to the type of strategy planned, as solutions

should be integrated into the pre-existing physical and institutional space of cities [14].

- *People, stakeholders, and community engagement:* In line with the participatory governance paradigm, the advancement of intelligent cities also requires engagement and active participation of all city actors. The socially inclusive and participatory nature of a strategy is what shifts the point of emphasis from a ‘smart’ to an ‘intelligent’ city strategy [6]. Engagement should not only refer to the identification and selection of potential solutions, but to the whole process of strategy design and implementation through testing, validation, and participation in dissemination.
- *Co-creation/crowdsourcing/co-development:* It is a fundamental trend of intelligent cities that solutions have to be defined and implemented with the involvement of citizens, consumers and users. The contribution of the latter as creators of solutions is necessary in all aspects of city life and activity, such as the new physical-digital work environments, smart infrastructure, utilities, smart solutions for quality of life and protection of the environment. This central role of users is transforming the traditional city planning model from top-down to bottom-up.
- *Technology solutions and infrastructure:* As information and communication technologies are vital elements in all smart cities, the strategy is expected to include a lot of digital services and infrastructure. Most common is the infrastructure offering ubiquitous broadband Internet access. On the top of that are sensors and technologies enabling data storage, processing, and visualization, as well as digital applications in many different domains, such as the urban economy, city infrastructure and utilities, quality of life, and city governance. The key challenges and basic components of every strategy should be, first, the identification of existing technologies, secondly, the embedding of technology into urban activities and projects, and, finally, the interoperability between e-services across different domains.
- *Sustainability:* The success of each intelligent city strategy depends not only on the selection of the best possible scenario and guidance during the implementation, but also on the long term viability of solutions implemented. High quality e-services and technology platforms entail significant cost, hindering the successful execution of any good strategy. Therefore, policy and concern for marketing and distribution of e-services and smart products, securing the necessary revenues in the long run, should be part of the design and an indispensable factor in deciding the best possible strategy scenario.
- *Monitoring and evaluation:* The measurement of intelligent city performance is essential in order to

document intelligent urban ecosystems. This activity is related to the selection of evaluation criteria and performance indicators of factors and characteristics that reflect the level of intelligence, efficiency, sustainability, and quality of life in the city.

The abovementioned elements provide a general orientation to city managers and urban planners. Nevertheless, questions still remain regarding how they could be integrated into a cohesive strategy with identifiable steps relevant for different types of cities.

3. PLANNING A SMART CITY DISTRICT: A PILOT PROJECT

A case study that can shed light on the processes of e-services design for smart cities is the creation of a smart commercial district in the city of Thessaloniki, Greece. This smart district was realized in the framework of the European project PEOPLE, which aimed at speeding up the uptake of smart city ecosystems through the rapid implementation, deployment, and uptake of innovative internet-based services. The pilot project was implemented in strong collaboration with the Municipality of Thessaloniki.

The project started with a detailed analysis of both the city environment and the local innovation system. The analysis revealed the spatial concentration of commercial, administrative, academic, and cultural activities combined with recreation and sports facilities, entrepreneurial, and research premises. However, the spatial proximity of the abovementioned activities does not seem to create enough synergy or some kind of complementarity in order to sustain a vivid commercial ecosystem. In the city, despite the large volume of people inflow (apart from the citizens there is a large number of people that work in the area), local businesses lose market share at the benefit of nearby larger markets and malls. This problem, which was revealed during the meetings with local entrepreneurs, is further accentuated by usual urban problems such as traffic congestion around the city’s main square, where the heart of the local market is, lack of street signaling and parking, pollution, and high urban density. Regarding digital infrastructure, although a wireless network is freely available in the city center, the digital applications and e-services offered do not correspond to the citizens' and merchants' needs and expectations. These challenges constitute both a weakness and opportunity for Thessaloniki to reinforce the commercial city center, improve its attractiveness and quality of environment vis-à-vis nearby markets and malls, through the design and implementation of smart city services and infrastructure.

The analysis of the city’s innovation ecosystem aimed at identifying actors of change: public bodies, public service providers, users, and companies that might guide the design of technological solutions and e-services. Many local stakeholders were contacted and their needs, ideas,

and motivation for collaboration were recorded. Despite the large number of stakeholders that were identified and participated in the meetings, only a few remained active until the end of the pilot project, mainly those that had some kind of direct interest in the solutions and services being deployed. Apart from the stakeholders a number of lead users were also identified. The term “lead user” refers to selected citizens and companies that offered information about both needs and solutions from leading practices in the community, being also the first users of ICT services.

The mapping of the city’s challenges and actors of change was followed by a horizon scanning to identify technologies, applications, and solutions that bolster commercial activities and local marketplaces. We focused on solutions related to mobility, urban information management, and e-commerce. A literature review identified about 20 different applications of intelligent transport systems, e-commerce, and ICT for tourism and leisure. Local merchants and managers also proposed solutions through a process of public consultation, organized in consecutive cycles.

Based on the conclusions of the survey in terms of challenges, communities, stakeholders, and available technologies and solutions that can make a city center more sustainable and attractive, a planning scenario was drawn. This scenario -combining a wide range of digital applications- was able to interconnect the different activities that take place in the area and offer a better environment in terms of access, commerce, and environment. The overall aim was the creation of a platform for a smart commercial district that would strengthen the commercial hinterland of Thermi’s commercial and business district, benefit from the huge commercial activity of nearby markets and malls, and provide easier access and better environment. The open consultation process concluded with the design of a platform composed of five components.

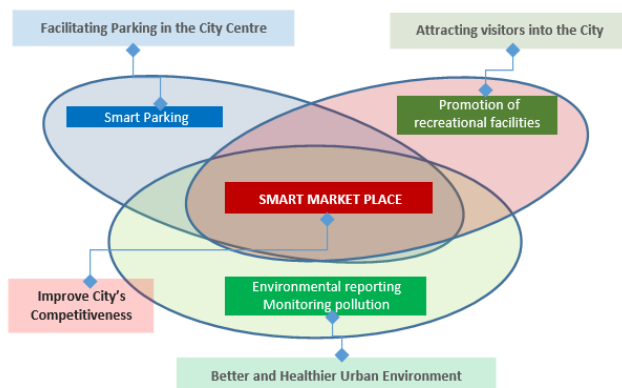


Figure 1: The Interconnected components of the Smart City platform, © P. Tsarchopoulos

At the core is the smart city marketplace to sustain the commercial activity of the central district and around four

complementary services that aim to improve the urban environment and offer better access to the area.

The implementation of the scenario included also the design and development of web and smartphone applications, as well as the deployment of hardware required for the provisioning of the e-services. The following five applications were created:

1. **Smart marketplace:** Creates a virtual marketplace managed by the local shopping community. It aims to support the local merchants and businesses, and is composed of four interrelated subsystems: a virtual marketplace with numerous individual e-shops; a business directory with description and location of professional and businesses on the map; an application for product offers and promotion; and customer assessment of e-shops.
2. **Improve-my-City** enables citizens to directly report non-emergency problems to the public administration and requests about local issues such as discarded trash bins, faulty street lights and broken tiles on sidewalks, illegal advertising boards, and suggestions for improvement and urban renewal. The reported issues are automatically transmitted to the appropriate office of the city administration so as to schedule their settlement. Apart from reporting a new issue, the application allows citizens to add comments or vote on most urgent issues and prioritize the action of the public authority. The platform also informs the citizens about the progress of the reported issue and facilitates the establishment of a two-way dialogue between citizens and the public administration [15].
3. **Virtual city tour:** Creates an engaging, interactive, collaborative community map of local sights and attractions. Users are able to submit photos and 360 degree panoramic virtual tours of their favorite points of interest and attractions.
4. **Sense the city:** A network of sensors that receives, collects, and visualizes air pollution data from sensors distributed around the city.
5. **Parking spaces availability:** Informs about free parking space in premises and open parking areas located in the city center. The parking inventory is updated regularly and delivered to users through web and Variable Message Signs (VMS).

Moreover, a number of hardware installations also took place, including: four environmental pollution monitoring stations; one car park capacity counting station; three outdoor electronic displays showing the available parking spaces in real time; and four interactive information terminals (info kiosks).

The platform is available at the address <http://smartcity.thermi.gov.gr>. Applications are

distributed under Affero GPL license from URENIO's GitHub repository (<http://icos-urenio.github.io/>).

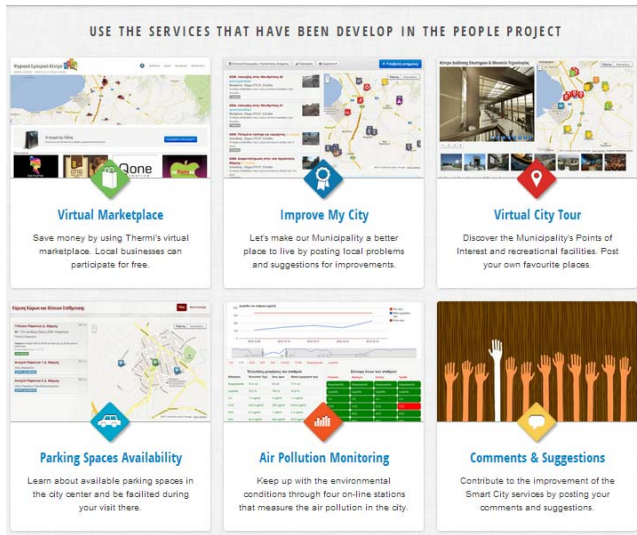


Figure 2: Homepage of the platform, © N. Komninos

The combination of hardware infrastructure and software applications creates a layer of smart city services that helps to improve the physical environment of the city center, enhancing its attractiveness and functionality. The deployed services are provided through the web and the users can access them using their desktop computer or their mobile phone. The connection between physical and digital space is achieved by using information kiosks equipped with touch screens in selected places, and Quick Response (QR) codes in front of stores and Points of Interest (POIs).

The applications were developed using both state of the art web technologies (HTML5, CSS3, etc.) and open source technologies (LAMP solution). The mobile applications are available for Android and IOS smartphones. The platform implements a service oriented architecture where services are autonomous reusable components. Services are self-contained and loosely coupled, meaning that dependencies between services are kept to a minimum. Instead of one service depending on another, coordination services are provided in situations in which multiple services need to be accessed in a sequential access mode.

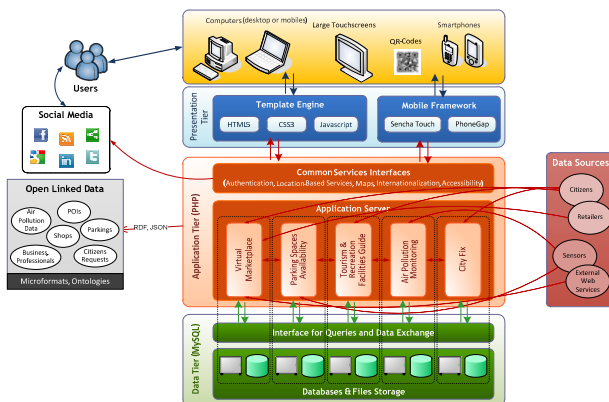


Figure 3: The architecture of the platform, © P. Tsarchopoulos

At the same time, apart from technical developments, the sustainability of the solution, i.e., keeping alive the deployed e-services after the end of the planning and initial funding, was investigated. There was a need of a business model that would provide a solution for continuous funding and financial viability. The Total Cost of Ownership (TCO) for the smart city services, after the initial deployment, is related to the cost of operation and management. The following categories were considered in the estimation of TCO: use, maintenance, upgrades, support services, training, software scaling, customization (change), and modification. In order to keep TCO low, the partners of the project made two strategic decisions:

1. Distribute the applications under an open source license, and
2. Follow a web 2.0 approach in data acquisition and update, taking the majority of data either from sensors or from users.

In this way, the city could limit the necessary funds needed to sustain the provision of e-services in the long run. Moreover, a number of business models for smart city solutions was considered and assessed, such as donations, reselling, advertising, free core service and paying for additional features, and public funding [16]. Then, a selection of suitable business models per e-service was made.

For the monitoring and evaluation of the solutions implemented, a number of criteria and indicators were used. These were defined per innovation cycle. Every cycle had its own metrics adjusted to its particular focus. At the end of each innovation cycle, results were evaluated thoroughly and the conclusions led to adjustments in the pilot's design. The assessment indicators fall into the following categories: (i) activation of stakeholders, (ii) activation of (lead) users, (iii) e-services, (iv) data model and information flows, and (v) design of business model and exploitation. Indicators capture the degree of mobilization and involvement of stakeholders and users, number of implemented e-services and their usage, the data model effectiveness, and the sustainability of solutions. Data that are related to the usage of e-services were automatically collected through web analytics. For the rest of the indicators, data were provided from the project stakeholders.

The measurement of performance of the smart commercial district was based on a scoreboard. It consists of a series of indicators that can be used to collect information and show advantages and disadvantages of different applications and e-services. Through the scoreboard indicators, it became possible to define the impact of user-driven methodologies and document that most successful solutions were those produced by the largest consultation with end-users and

stakeholders. The main aspects of the scoreboard were about the local economy, smart infrastructures, governance, and citizens.

The progress of the pilot project was further stimulated by the integration of innovative technologies, new features in the applications, improvements suggested by users, creating a continuous process of e-services and technology update and evolution.

4. SMART CITY PLANNING: A ROADMAP

Taking into account the smart city planning processes reviewed in Section 2 and the case study on the design of a smart city ecosystem discussed in Section 3, it becomes feasible to outline a holistic methodology roadmap for planning intelligent/smart cities.

The roadmap we propose is inspired by strategic planning principles and unfolds in three stages, which are subdivided into seven different steps overall. The first stage includes Steps 1-3, the second stage includes Step 4, and the third stage Steps 5-7 as illustrated in Figure 4.

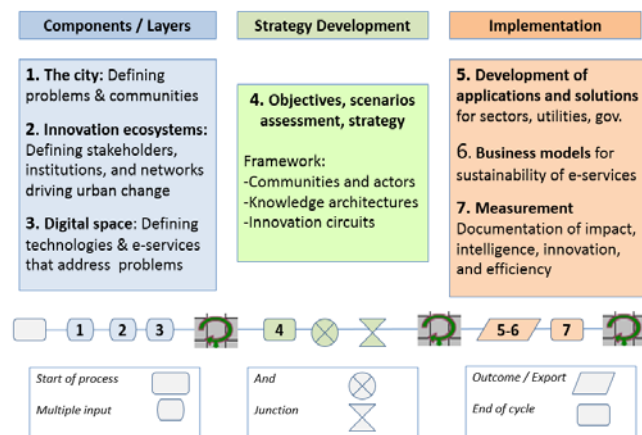


Figure 4: A roadmap for intelligent city planning: Three stages and seven steps, © N. Komninos

The first stage takes into account the main building blocks of intelligent cities (urban system, innovation ecosystem, digital environment); the second is about the integration of those components and elaboration of a user-driven strategy of innovation to address the problems initially stated; the third stage concerns the implementation of a strategy by developing digital applications, the selection of business models for the sustainability of e-services, and measurement system and indicators .

The rationale behind these stages is to ensure

- the interconnection of digital applications and services with city problems and challenges,
- the integration of digital services with the physical and social space of cities, and
- the actualization of participatory processes among stakeholders, end users, organizations, and

citizens for the selection, creation and enhancement of digital solutions and services.

Step 1. The city: Defining challenges and communities

Intelligent cities as a planning model today and an urban reality in the near future do not modify the intrinsic logic of cities, forged through centuries of urban life. Cities emerge from blind market forces and chaotic individual decisions and choices, but also from strategic planning and detailed urban design. Agglomeration is the major driving force of cities and the spatial concentration of population and economic activities create positive externalities and beneficial systemic effects due to collaboration. Driven by forces of agglomeration, every city presents two interconnected faces: (1) a community and political association for collaboration and problem-solving and (2) an agglomeration of resources, characterized by divides, inequalities and problems.

Intelligent city planning starts from those deep city structures related to challenges and communities, which set out a reference framework that pre-exists any city transformation towards a more efficient and intelligent management. City intelligence stems from the very nature of cities: active communities, collaboration, and beneficial systemic effects. Defining challenges and communities that can address those challenges is the starting point of any intelligent city planning process.

Considering the more practical tasks in this initial step of the roadmap, a series of issues has to be taken into account and carefully examined. These fall into two inter-related areas:

- Defining one or more domains of intervention in terms of city sectors, cluster, and utilities, etc., in order to address problems and reach objectives within these domains. A sufficient amount of data is needed both to document problems that need to be solved and to describe the baseline, the actual situation of the domain.
- Mapping communities related to challenges and objectives, and assessing the governance capacity of those communities. Various actors should be identified within these communities such as authorities, organizations, companies, stakeholders, citizens, and users. They are expected to contribute by devising solutions to the challenges identified and develop a more intelligent behavior.

Step 2. Innovation ecosystem: Stakeholders and crowds driving urban change

Behind the apparent structure of cities, we may find a nexus of innovation ecosystems, composed of stakeholders, suppliers, producers, and users that take decisions and influence the future of cities. Such functional innovation

ecosystems pave the way in which cities districts change, how activities are added or removed, and how city districts and infrastructures adapt to changing demand and user needs.

The second step of the roadmap examines the fundamental drivers of city change, namely, the innovation ecosystems of city districts, clusters, and utilities. The purpose here is twofold:

- to map innovation ecosystems which are closely connected to the urban system, by describing their composition, stakeholders, decision-makers, networks of collaboration locally and globally, and
- to understand the forces that introduce innovations in the urban system and define the governance, operation rules, institutions, decision-making processes of change, and the actors involved in these processes.

Intelligent cities are expected to enable every citizen and organization in the city to fulfil their own personal goals and expectations within environments that enable collaboration and “innovation-for-all”. They are expected to achieve this vision thanks to vivid innovation ecosystems augmented by smart environments and improved cognitive abilities and resources.

Step 3. Digital space: Horizon scan of available technologies and solutions

The third step of the roadmap investigates the digital space of cities and performs a horizon scan of available solutions at local and global levels.

The creation of the digital space of intelligent cities is guided by two complementary yet distinct processes: (i) digital planners and IT developers may use existing solutions, off-the-shelf software applications that have already been used in other cities and recognized as good practices for the management, sustainability, and development of cities, (ii) alternatively, they can try creating something from scratch, developing new solutions and applications by using available technologies, research, and the creative communities of the cities concerned. In both cases, the deployment of digital solutions relies on a series of information, communication, and programming technologies, most of which have become available over the last 15 years. These technologies are evolving and changing at an extremely rapid pace. Within a short period of time from the mid-1990s until now, we can already distinguish many consecutive and overlapping waves of web technologies and corresponding intelligent city solutions that have emerged gradually. These technologies offer different types of spatial intelligence and solutions to urban problems. The purpose of the horizon scan is to avoid reinventing the wheel and get profit from existing solutions that can be adapted to challenges defined at the start of the roadmap.

The continuous evolution of web technologies from the static web to the social web, the real-time web, cloud-based solutions, the semantic web, and eventually to the intelligent web in the near future, widens the options for constructing the digital space of cities. There is a stack of available technologies and existing solutions, which any type of planning has to take into account. Nowadays, for instance, intelligence moves out of web applications and enters into the domain of data: the meaning of data becomes part of data, data are provided just-in-time, and real-time data enable real-time response.

Thus, this step of the roadmap is mainly a horizon scan and search for best practices in digital applications and solutions which have been implemented successfully and have provided positive results to urban challenges.

Step 4. Strategy: Objectives and scenarios of spatial intelligence and innovation

Step 4 is, actually, the second stage of the roadmap. It focuses on the activation of the 'golden triangle' of intelligent cities: the integration of 'city communities and challenges', 'innovation processes', and 'smart environments' into a coherent array that can optimize the functioning and decision making of the city. Thus, the second stage of the roadmap includes only one -but most demanding- step: elaborating a strategy of spatial intelligence and innovation to address the challenge(s) initially defined.

The strategy to be developed at this step appears as a sequence of objectives, scenarios, use cases, applications, and collaborative solutions. Taken together, these elements establish a strategic plan for the intelligent city, including projects and solutions that augment the collective intelligence of cities. Balanced scorecard methodologies may be extremely useful in achieving coherence among challenges, objectives, actions, targets, and metrics. Thus, strategy development is mainly about integration and creativity. Integration in the sense of bringing together the components of intelligent cities, communities of actors, innovation and problem solving processes, available digital technologies. Creativity in the sense of developing new solutions beyond the state-of-the-art, while focusing on specific problems and a unique context.

In previous publications [17, 18] we extensively discussed different strategies that can be used to achieve integration of spatial, social, and digital elements of intelligent cities. We referred to *agglomeration intelligence* produced by the spatial concentration of digital applications; *orchestration intelligence* based on organized top-down collaboration within a community, connecting people's skills, collective intelligence processes, infrastructure and machine intelligence; *empowerment intelligence* based on people's learning, up-skilling and talent cultivation over open platforms and infrastructure offered by the city; and

instrumentation intelligence based on streams of data generated by sensors and smart meters, that capture the working of cities and enable informed decisions to be taken by citizens and organizations.

Step 5. Development of applications / solutions

The third stage of the roadmap includes three steps dealing with strategy implementation: development of applications and solutions; selection of business models turning applications to e-services; and measurement and impact assessment. Implementation, however, is not a linear process going through these three instances, but takes place in circular loops, each one changing the configuration of the other instances.

The development of applications and smart city solutions should take into consideration issues concerning users, architecture, hardware and software requirements, quality attributes, data, security, licensing, and sustainability. Software development can choose between different solutions of control and collaboration. Control options range from using proprietary software, through a usage permission granted according to a license which describes in detail the usage conditions, to Free Open Source Software (FOSS) which offers full control over the software through an ex-ante agreement about the rights to use, modify and distribute software. Collaboration options range from full in-house development to external collaboration with local or global developers. The collaboration or development model is independent from the software control model, as collaboration can take place both in proprietary software and FOSS.

Major domains of application creation are those related to:

1. *the innovation economy of cities*, focusing on production sectors or production clusters or sectors of manufacturing, logistics, financial services, business services, commerce, tourism, etc.;
2. *living in the city*, focusing on consumption and well-being, health and education, improving of quality of life, bridging social and digital divides, monitoring the environment, offering safety in the public space, and social care services;
3. *city infrastructure and utilities*, focusing on networks and services of transport and mobility, energy, water, waste, and broadband; and
4. *city governance*, focusing on city management and operation, decision-making and democracy, city planning, administration services to citizens, monitoring and measurement of city performance.

Step 6. Selecting a business model of sustainability

The purpose of developing broadband infrastructure and software applications is to offer new e-services and capabilities to citizens, companies, and organizations of the city. However, there is strong discontinuity between

software applications and the provision of e-services, which is created by needs for funding and revenue generation that can keep IT infrastructure and e-services running.

The functionality of business models is to bridge such gaps providing solutions for funding and financial viability. Business models deal with the financial aspects of smart city strategies and solutions. They cover both the sources of the initial investment and the funding of the operation. Thus, a business models is much more than a business plan calculating costs and revenues. It is a creative solution for securing the necessary funds of initial investment and revenue for the long term operation of services and maintenance of infrastructure.

Step 7. Measurement of spatial intelligence

In this final step of the roadmap, the major concern is to document that intelligent city solutions do in fact offer higher spatial intelligence and improve the quality and performance of cities. Measurement and assessment of intelligent city performance is about the monitoring of Key Performance Indicators (KPIs), the creation of scoreboards, the gathering of data and analytics, and about understanding the factors shaping the performance of cities. Measurement is indispensable as most dimensions of spatial intelligence are usually hidden at first glance.

Measurement should take into account baseline conditions of the urban space, planning efforts, and the impact of smart city solutions in a sequence shown on Figure 5. A new standard, known as ISO 37120, was recently defined by the International Organization for Standardization, which outlines indicators that cities should use to assess their performance and compare with peer cities around the globe.

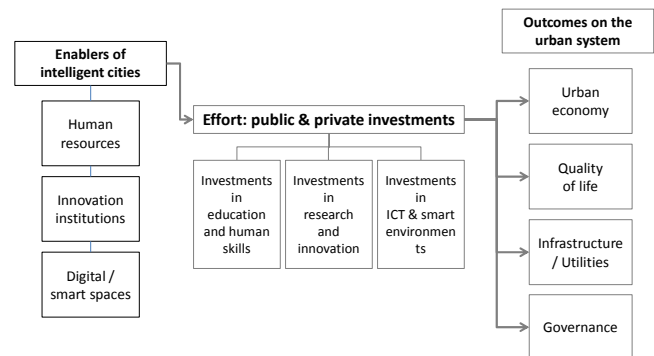


Figure 5: Main KPIs for monitoring intelligent cities, © N. Komninos

This ‘3 stages - 7 steps’ roadmap was designed to ensure the integration among the three major components of intelligent cities, namely the ‘urban space’, the ‘innovation ecosystem’ and the ‘digital or smart environment’. It is a strategic planning roadmap for the city overall, not for the digital space and software applications only. The prime objective is integrate all enablers of city intelligence

(human resources, innovation institutions, digital tools) and introduce more efficient ways of operation in all aspects of cities, physical, social, and environmental.

Is the design of the roadmap successful? This is a key question, which we may assess with respect to users, developers, and the public administration response.

The roadmap gave priority to user-driven innovation and bottom-up generation of solutions for sustainability and growth. This is a fundamental trend of smart cities that solutions have to be defined and implemented with the involvement of citizens, consumers and users. In the case of Thermi, the contribution of users was massive and took place at all stages of e-services design and implementation: definition of challenges, concept design, prototypes, beta testing.

The roadmap has also achieved a good involvement of developers. The choice of open source licenses, the development upon Joomla, and the use of open infrastructures such as the Github and Sourceforge enabled the contribution of developers from all over the world. Within a few months after the release of Improve-my-City, the application was translated in 23 languages, was implemented worldwide, and smartphone applications were created.

The most positive aspect of assessment came from the public authority and the internal re-organization of the public services in order to comply with citizens' requests and suggestions.

In conclusion, with the implementation of the roadmap, cities can become organized along a connectionist-cyclic model in which, citizens and organizations produce collective intelligence, combine distributed knowledge, and accumulate resources to improve the economy, life and infrastructure of cities. In this model, higher efficiency is structural and system implicit: user-driven innovation works as engine of novel solutions and smart environments work as facilitators of communication, networking, information processing, real-time response, and ultimately innovation.

5. REFERENCES

- [1] N. Komninos. *Intelligent Cities: Innovation, Knowledge Systems and Digital Places*, Taylor and Francis, London and New York, 2002.
- [2] DG for Internal Policies. *Mapping Smart Cities in the EU*, Policy Department A: Economic and Scientific Policy, January 2014.
- [3] H. Chourabi, J. Ramon Gil-Garcia, T.A. Pardo, T. Nam, S. Mellouli, H. Jochen Scholl, S. Walker and K. Nahon. Understanding Smart Cities: An Integrative Framework, *45th Hawaii International Conference on System Sciences (HICSS)*, January 2012.
- [4] Accenture. *Building and Managing an Intelligent City*. Online Report, 2011.
- [5] N. Komninos. The Architecture of Intelligent Cities. In *Intelligent Environments 06 Conference proceedings*, pages 13-20, Institution of Engineering and Technology, Athens, July 2006.
- [6] S. Hodgkinson. Is your city smart enough? Digitally enabled cities and societies will enhance economic, social and environmental sustainability in the urban century, *OVUM Analyst Insight*, March 2011.
- [7] A. Abdoullaev. A smart World: A Development Model for Intelligent Cities. *The 11th IEEE International Conference on Computer and Information Technology (CIT-2011)*, Cyprus August-September 2011.
- [8] Cisco. *Cities in the Cloud. A Living PlanIT Introduction to Future City Technologies*, Online Report, 2011.
- [9] N. Komninos, M. Pallot, and H. Schaffers. Introduction, *Journal of the Knowledge Economy*, Special Issue on Smart Cities and the Future Internet in Europe, 4(2):119-134, June 2013.
- [10] S. Zygiaris. Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems. *Journal of Knowledge Economy*, Special Issue on Smart Cities and the Future Internet in Europe, 4(2):217-231, June 2013.
- [11] IDG Government Insights. *Smart City Strategies*. Smart City Framework, Document No.GI234160, 2012.
- [12] IBM. *The modern city – from vision to reality*. Online Report, IBM Corporation, 2011.
- [13] IBM. *How Smart is your City? Helping cities measure progress*. IBM Global Business Services, Institute for Business Value, Executive Report, 2009.
- [14] N. Komninos and P. Tsarchopoulos. Toward Intelligent Thessaloniki: From an Agglomeration of Apps to Smart Districts. *Journal of Knowledge Economy*, Special Issue Smart Cities and the Future Internet in Europe, 4(2):149-168, June 2013.
- [15] I. Tsamboulatidis, S. Nikolopoulos, D. Ververidis, I. Kompatsiaris, P. Tsarchopoulos, N. Komninos. ImproveMyCity – An open source platform for direct citizen-government communication, *ACM Multimedia, 2013 Conference Proceedings*, October 2013.
- [16] J. Bélissent. *Getting Clever About Smart Cities: New Opportunities Require New Business Models*. Forester Research. 2010.
- [17] N. Komninos. Intelligent Cities: Variable geometries of spatial intelligence. *Journal of Intelligent Buildings International*, 3(3):172-188, August 2011.
- [18] N. Komninos. What Makes Cities Intelligent? In M. Deakin (ed.) *Smart Cities: Governing, modelling and analysing the transition*, pages 77-95. London and New York: Routledge. Permission granted by Taylor and Francis, 2013.