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Smart City Reference Model: Assisting Planners to Conceptualize the Building of Smart City Innovation Ecosystems

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Abstract The objective of this paper is to address the smart innovation ecosystem characteristics that elucidate the assembly of all smart city notions into green, interconnected, instrumented, open, integrated, intelligent, and innovating layers composing a planning framework called, *Smart City Reference Model.* Since cities come in different shapes and sizes, the model could be adopted and utilized in a range of smart policy paradigms that embrace the green, broadband, and urban economies. These paradigms address global sustainability challenges at a local context. Smart city planners could use the reference model to define the conceptual layout of a smart city and describe the smart innovation characteristics in each one of the six layers. Cases of smart cities, such as Barcelona, Edinburgh, and Amsterdam are examined to evaluate their entirety in relation to the Smart City Reference Model.

Keywords Urban innovation ecosystems · Smart cities · Intelligent cities · Green cities · Sustainable cities · Innovating cities

Introduction: The Need for a Holistic Framework for Conceptualizing Smart Innovation Ecosystems

The evolutionary study of smart urban environments revealed different conceptions of what is often called "smart city". Following the traditional regional and neoclassical theories of urban growth and development, the Smart Cities [1] project identified six axes or dimensions. These smart city axes are outlined by Caragliu et al. [2] as: smart economy; smart mobility; smart environment; smart people; smart living; and, finally, smart governance. Moreover, Toppeta [3], Cozens [4], and Greenburg [5]

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outlined the growing demand for a more efficient, sustainable, and liveable model in urban development, highlighting the conception of "sustainable cities", by setting the environmental and social sustainability as the clear vision of smart cities [6, 7].

The term "smart city" is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth addressed by Atkinson and Castro [8], Belisent [9], and Shapiro [10]. These aspects lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of CO_2 emission [8, 9, 11–21], "interconnected" related to revolution of broadband economy stated by [19, 20, 22, 23], "intelligent" declaring the capacity to produce added value information from the processing of city's real-time data from sensors and activators [24, 25], where as the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation [10, 26] based on knowledgeable and creative human capital [27]. While each one of these smart city conceptions pictures partially the smart city vision, they all contribute significantly towards growth and sustainability.

Cities prioritize their urban innovation ecosystems from their traditional urban character to innovative "green", "smart", "open", "intelligent", and "innovating", aiming towards environmental and social sustainability. This paper uses the generalized term "smart city" to describe all these various smart environment conceptions. Even though this arbitrary generalization is not scientifically accurate, it is rationalized by the high exposure of the term "smart city" as a generic term to describe IT-based innovative urban ecosystems.

The publicity that the smart city concepts have gained nowadays (with more than 2,000 Google meaningful search results) has led to frequent and arbitrary self-declaration of cities as "smart". While there are several benchmarking and evaluation frameworks on smart cities and communities based mainly on statistical data and quantitative information, i.e., the Intelligent Community Forum [28] or the Smart Cities index [2, 1], there is a need for analytical tools that could enlighten smart city's planning processes. The paper attempts to demystify the complexities of smart city conceptions, through the lens of smart city planning, by answering the following questions:

- Could all conceptions and diverged policies and processes related to smart city planning be assembled into an inclusive and holistic smart city reference framework?
- How such a framework would be assistive in identifying processes within the urban innovation ecosystem that compose a smart city's plan?

An Analytical Framework for a Smart City's Innovation Ecosystem

Literature review enables assemblies of smart city dimensions into a holistic conceptual reference model. The investigated innovative urban policy paradigms inter-relate issues of green cities, connected life, intelligent communities, innovation ecosystems, and environmental and social sustainability with urban growth.

Regardless to say a smart city master plan needs an orchestrator with executive and policy planning authority, such as the city's council. Creating a smart city from

scratch requires leadership to monitor the plan. This top–down approach in master planning smart cities (i.e., Barcelona) must be balanced with the ability to constructively engage local stakeholders (i.e., Amsterdam) into a hybrid model that combines central city monitoring with bottom up community participation.

Another issue that this paper is exploring is the bond of green and sustainable investments with the smart city socio-technical and financial concepts. It is in line with the work of Adams [11], Blewitt [21], and MGeough and Newman [7] regarding smart urban sustainability and urbanization theories [5]. Green city layer (1), in Fig. 1, flags smart city sustainability and rivals smart city solitary ICT-based narrow conception. In turn, technological breakthroughs, people, and innovation processes build upon green city to bring a sustainable future. Conclusively, green economy rationalizes the decision for smart city investments.

Broadband wide coverage along instrumented and application layers hearted the smart city definition in layers (2, 3, 4, and 5). The flagship of the transformation of the digital to smart city is the city-wide access to real-time information. This outcome has also appeared in the work of Bell et al. [19] and Ford and Koutsky [29]. Thus, the

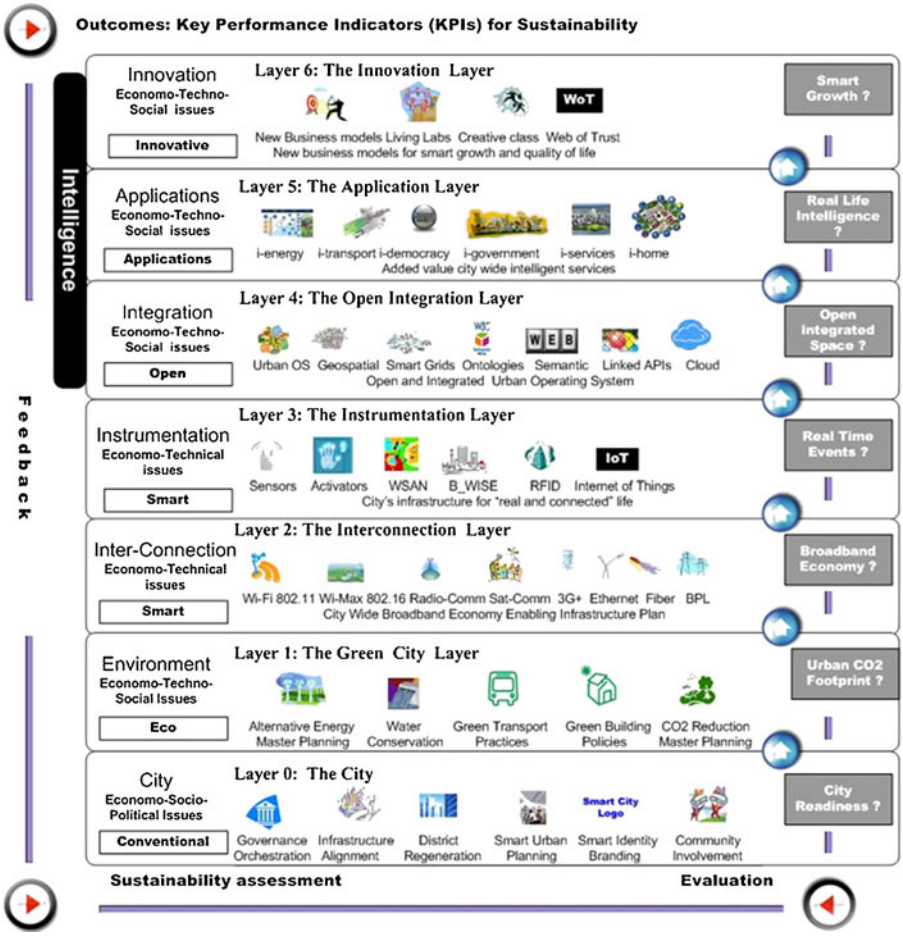

Fig. 1 Smart city conceptual reference model

interconnected, instrumented, and application layers are distinguishing parameters to estimate city's "smartness". While the processing of historical information through data mining and agents is an important intelligence capacity to revitalize urban economies, real-time data intelligence heartens the "real life" concept of smart cities [30–32].

Smart cities must undertake open access and inclusive strategies to diminish the digital dividend, in layer 4, also argued by Partridge [33]. The smart city vision should be realized through public-controlled integrated urban operating systems to evade vendor monopolies and offer unrestricted data to all citizens versus carving out virtual gated communities and corporate enclaves. Urban performance currently depends not only on the city's endowment of smart capital, but also, on the availability and quality of human and social capital. At layer (6), innovation ecosystems must afford an opportunity for city leaders to approach seemingly intractable issues from a smart perspective and capitalize on new smart city business models explicitly defined by Belissent [9] and MGeough and Newman [7]. The conceptual reference model follows a layered approach to describe smart urban environment conceptions along with their innovative structural components and processes and the addressed global challenges.

Layer 0: The City Layer

Belissent [9] denotes that smart cities must start with the "city" not the "smart", emphasizing that smart city notions must be grounded to the context of a city. This layer conveys the traditional components present in every city. It is an important denominator to the readiness of cities in absorbing smart features [9]. Cities consist of districts (commercial, academic, science, entertainment, logistics zones, industrial, residential) that underpin their socio-economic characteristics of their labor market [4]. City's infrastructure (utility networks, streets, transport) are urban constructs managed by the municipal authorities. Citizens and communities are the human engine of cities that have a behavioral influence to city's historical and cultural heritage.

For every city, in its conventional terms, there are certain operations and processes that must be synchronized toward obtaining a smart city's vision responding to certain challenges. These challenges refer to the enrichment of a city's urban planning with smart planning activities and to the type of infrastructure intervention, which are planned to complement smart city actions. Another critical factor is the ability of the city to create an identity for smart priorities, which blend with the city's plan and innovative outlook. A smart city's identity must be aligned with regeneration projects, planning to change, and social innovation actions that should be taken to create a socially inclusive smart city vision among citizens and communities [4, 9].

Layer 1: The Green City Layer

The green city layer is inspired from new urbanization theories raised by Greenburg [5] and LEED Leadership in Energy and Environmental Development initiatives [34]. A city's sustainable future is mutually attached to smart city structures. Green cities are emerging as holistic playgrounds for smart cities toward sustainability. In this

layer the green city infrastructure creates a fertile founding environment, where broadband networks, sensors, and smart grids could lead to intelligence and create environmental impact [5]. As an example, the Smart Cities Initiative of the European Union's SET-Plan [35] proposes to progress by 2020 towards a 40% reduction of greenhouse gas emissions through sustainable use and production of energy through smart city technologies.

The moderation of these urban planning challenges of layer 0 into green city priorities demands innovative forms of green governance, policy integration, and allocation of financial resources to develop a suitable mix of a green urban ecosystem. In green city layer policy makers are challenged with the definition of green city constituents for CO_2 footprint reduction, in conjunction with city's involvement in alternative energy plans. These green policies must be set also in terms of green transport management and green building specifications [5, 34, 36].

Layer 2: The Interconnection Layer

The green city layer is integral to the smart city concept referring not only to "infrastructural green islands" but also to city-wide diffusion of green economies. The urban-fiber connects green and broadband economies as the initiatory step to smart and connected city. Moreover, broadband strengthens city economic capacity [19] and enhances social inclusivity [29] through the holistic coverage of city's terrain, connecting physical communities as they live, work, learn, and play. IBM [37] has conceptualized the smart "interconnected, instrumented, and intelligent" city, where services for home, work, school, hospitals, malls, businesses, travel, and government aimed towards the improvement of quality of life.

This layer refers explicitly to the innovation support capacity of the telecomm infrastructure to interconnect people, smart nodes, workstations, and other embedded devices and provide high-speed network access to a city-wide area. Smart city planners must address the challenge of city-wide broadband coverage including underdeveloped districts and the range of free access to cyberspace [19, 29].

Layer 3: The Instrumentation Layer

Cities, as urban machines of real events, require real-time system response. They comprise of real-time connections outlets such as radiofrequency transmitters, traffic signals, streets, smart meters, infrastructure sensors, and traffic and transit sensors [38]. In fact, the availability of real-time data is the constituting element of smart cities connecting the physical world with the information world and is the distinctive procurement that justifies the dynamic term of "smartness" [30, 39]. Internet of Things, as a realization of digital into the physical world is expected to greatly contribute to addressing today's urban challenges [24, 39, 40].

Radio Frequency Identification, wireless sensor and actuator networks, and networked Embedded Devices enable high-level access and utilization of the real-world data and resources. The next generation of Internet technologies [20] would be able to communicate with devices attached to virtually all human-made objects because of the extremely large address space of IPv6.

All these real-time devices are connected into the city fiber through the interconnection layer (2), they are monitored through the integration layer (4), and nourish intelligent applications in layer (5) with real-time data. Smart planners must decide upon the extent of real-time data sources into a "real and connected" city vision [30, 39].

Layer 4: The Open Integration Layer

Smart cities applications should be able to intercommunicate, and share among others data, content, and services. A key success factor for smart environments is the provision of open and distributed information storage, for all the embedded or not systems, implemented with different technological platforms [41]. Smart city platforms visualize urban space through geospatial databases, capture embedded information, and monitor intelligence applications, including smart energy grids [42], as urban operation systems.

Future Internet trends and motivations have a catalytic effect on smart city's interoperability, offering new opportunities for open web services through linked and open data [20]. Ontologies and semantic web services provide an important interoperable data representation standard. Languages like W3C, RDF-S, and OWL enable the exchange of data across city's domains by collecting intra-domain concepts and defining relationships among them. Visualization APIs (Google Visualizations API, MIT Simile Exhibit API, and Yahoo pipes) expose data on the web on a common visualization structure. At the same time, the trust and safety of the Internet shortcoming is attempted to be alleviated through the emerging research area of Internet of Trust. Another aspect of the open integration layer is the storing and accessing of applications and computer data often through a Web browser in cloud computing [43].

The city's ability to moderate, integrate, and make openly available smart digital resources is an important smart city monitoring process. For example, a platform in layer (4) resides on fiber-optic network, layer (2), in which water pipes with sensors in layer (3) provide real-time data to water utility optimization applications of layer (5). Santander's [44], layer (4), smart city platform stimulates the development of layer (5) applications by connecting the urban setting with more than 20,000 sensors. Smart planners are challenged with the effectiveness of the integration of various smart city applications and with the degree of "openness" of these resources to "any" [20, 41, 42].

Layer 5: The Application Layer

Smart cities mirror the real-time city operation pulse as system with systems. Cities are also being empowered technologically, as the core systems on which they are based become instrumented and interconnected, enabling new levels of intelligently responsive operation. The system incorporates infrastructures, such as broadband networking, smart grids alongside various forms of renewable energy generation and building new systems of mobility based on distributed networks. The system involves interconnected and instrumented real-time operators that run on real time and historical data and provide intelligence through several forms of ICT applications

such as smart energy grids, intelligent transport, e-traffic, e-payment, and e-government [3].

The concept of smart cities offers a revolutionary vision of urban sustainability. Utilizing the intelligent application of new technologies, smart cities also incorporate considerations of social and environmental capital in order to transform the life and work of cities. The urban space is where many of the solutions for a smart sustainable world intersect. Operationally, cities are based on a number of core systems composed of different networks, resources and green city infrastructures in layer (1). Layer (0) key functional city services, citizens, business, transport, communication, water, and energy are designed specifically for applications in urban resource management, interconnected with people and resources instrumented by power sensing, in layer (3), capitalizing on open web-based solutions, in layer (4), creating intelligence, in layers (5and 6) and optimizing the use of city instrumented assets from processing real-time data streams. Smart planners must develop policies and measures to extend the impact and diffusion of intelligence into the urban terrain, i.e., center, districts, streets, homes [3].

Layer 6: The Innovation Layer

Smart cities create a fertile innovation environment for new business opportunities. Leon [25] in his work, “The Well Connected City” has identified two main factors that are necessary to become a successful smart city and innovation hub [45]. First is the need to transform the quality and efficiency of public infrastructures and services. Secondly, a smart city must be an attractive place for doing business. Emerging technologies push for instrumented, interconnected, and intelligent in nature cities to accelerate their journey towards sustainable prosperity by making use of new “smart” solutions and management practices.

Smart cities form a dense innovation ecosystem with extensive social interactions from a knowledge workforce that creates economic value through the acquisition, processing, and use of information [46]. The articulation of smart city infrastructure through social networks and communities, legal and cultural systems, and various forms of social inclusive principles is endorsed by smart city policies for social sustainability. Cities with more educated populations experience more rapid growth [10].

The cooperation of innovation strategists with urban leaders could produce new business opportunities that ensure the long-term viability of smart city projects Belissent [9]. Business models must specify who the participants involved are, what functions are performed by each participant, what the technology and service assumptions are, what the funding and ownership provisions are, what the key business terms between the participants are, and what product and pricing strategies will be employed. For example, decarbonization of energy system requires radical innovation. This leads to new networks and strategic alliances from project-oriented case by case cooperation to joint strategic processes based on soft governance in stakeholder processes.

New business models are encouraged by e-democracy and e-participation, which raise the public’s "digital awareness". Smart planners are challenged with a city’s innovative ability to capitalize on smart city opportunities, simulating the response of

urban innovation ecosystems to create a more innovative culture that attracts leading edge individuals and businesses [7, 8, 47, 48].

Although there is not a unified approach to resolving urban issues, even on seemingly similar subjects (for example, water, energy, and environmental degradation), the conglomerate of the diverse notions and interpretation for smart cities are beginning to form a comprehensive structural framework for conceptualizing a smart city's urban innovation ecosystem.

Applying the Reference Model: Smart City Planning Experiences

Existing cities impose urban retrofit policies to address urban challenges. The pathway from conventional urban to innovative planning passes optimally from green, interconnected, instrumented, intelligent, open, and innovating development stages assembling complementary processes that mirror a smart city's plan [11, 21]. The Smart City conceptual reference model could be used by smart city planners as an analytical tool to identify the innovation processes and policies that complement a city's smart city plan. The proposed conceptual reference model is used as an analytical framework to analyze the smart city plans for the cities of Barcelona, Amsterdam, and Edinburgh.

Barcelona: An Integrated Layer Structure

The City of Barcelona Barcelona has developed the world's leading districts in tourism, finance, culture, and high technology. 22@Barcelona [17] is building a new compact city, where the most innovative companies coexist with research, training, and tech transfer centers, as well as housing (4,000 new subsidized residences), facilities (145,000 m^2 of land) and green areas (114,000 m^2). Barcelona *smart planning integrates with urban planning* with a distinctive "22@Barcelona" *identity*. The city's *regeneration projects* coexist with the neighborhood's industrial heritage thanks to the Industrial Heritage Protection Plan, written jointly by 22@Barcelona and the Barcelona City Council, which conserves 114 elements of architectural interest.

In 2009, Barcelona City Council [16] presented its "Smart City" model to improve its residents' quality of life and ensure a more efficient and sustainable future. This strategic positioning is in balance with the city's modern urban planning. The initiative aims to achieve Barcelona's 2020 vision [18] of becoming a global reference model for the development of an urban innovation ecosystem. These aims responds to future challenges, since the city is facing an urban wave and may be beginning to show lag-time between its dazzling, international image and socio-economic change. Furthermore, development-saturation is creating problems of increasingly difficult accessibility within the city.

Barcelona Smart City "22@" [17] identity is lead by the city council [16] as the orchestrator for sustainable economic, environmental, and social changes, in which city planning provides high-quality opportunities for people to live and work. High-tech zones such as 22@ [17] enhance the branding and outlook of Barcelona's urban innovation ecosystem. Regeneration projects for Barcelona Smart City [17] are integrated with smart planning. Eixample district initiates the first transformation

stage, a green city district expansion of 520 street blocks, with high-quality architecture, egalitarian design, and ease of access is a model for modern city urban design. The 1992, Olympics Games used a vehicle for city-wide reforms, overcoming serious urban degradation issues, and has regenerated under-developed areas and neglected industrial districts. The third wave of transformation arrived with high-tech zones such as 22@ [17], the Diagonal Mar hyper-community district and e-district of Poblenou [18].

Barcelona's smart planning follows a top–down design approach, which ensures a comprehensive smart city plan. On the other hand, it is not evident the presence of community initiatives as essential particles in the smart city planning process. Despite this criticism citizens enjoy a wide range of end-user ICT inclusive services. In pARTicipa 22@ [17] citizens participate in cultural events with three big screens where users can share media services. Tag cloud Opinions allows people to feel more involved and engaged to take an active part during live events, by creating, sending, and sharing personal contents through mobile phones. With Web 2.0 based on mobile phones, people express their ideas, share contents, and know what is happening in real time in other city places. Inclusive Community Barcelona's Urban planning [18], such as "22@Families on-line", also includes inclusive strategies reducing the potential conflict that will be generated by wealth and poverty in very close proximity, such as the €141 million La Mina project [18].

Green Barcelona The city operates under an innovative green plan for CO_2 reduction including *alternative energy, transport management, and green building policies*. Barcelona is the city with the highest density of solar panels in Europe. In 2006, solar panels covered 40.095 m^2 of the roofs on buildings, and in solar arrays, such as the Forum Esplanade of 10.500 m^2 solar panel surface [16]. During the last decade the entire water supply system in Barcelona has been adjusted to be powered by solar energy, aiming to provide all residents with warm water, with infrastructures such as the Solar Thermal Ordinance that addresses private and public homes, hospitals, restaurants, and office spaces. Since 2000, city's regulations require all new buildings to have solar energy sources installed. The city launched a program that aims to have 15 electric motorcycle/scooter charging stations which offer free charging, at least until 2012, installed around the city. Solar-powered, dynamic-information bus stop gives the public information on incidents and when the next bus will arrive. The City Council is also launching a hybrid bus prototype [18].

Interconnected Barcelona The *city-wide broadband coverage* enables broadband economies [19]. Barcelona WiFi is a Barcelona City Council free service that enables residents to connect to the Internet through WiFi access points, or hotspots, located in various municipal amenities and public access points [17]. There are WiMAX base stations, which were connected to the core network via 50 MBit/s microwave backhaul. Each base station is equipped with three sectors, each on its own 10 MHz channel in the 2.5 GHz band. "Fiber optics in homes" is a pilot project to install a fiber optics network inside homes in Poblenou to multiply the area's bandwidth. "T-City Friedrichshafen" is a digital city network that boosts data transfer application with the implementation of ultra fast fiber and mobile networks, which has over 300 km of optical fiber and is set on becoming the base management model of the city's intensive use of information technologies [17].

Instrumented Barcelona The city generates a high volume of real-time data spread realizing the well-connected city [31]. Wireless sensor and actuator networks, networked embedded devices enable high-level access and utilization of the real-world data and resources involving parking sensors, traffic flow, pollution, and noise sensors. Sensors are dedicated to monitor garbage capacity in urban dumpsters and improve waste management [17]. There are sensors for intelligent management of forested lands and for the maintenance and irrigation of green zones. Traffic lights, following a public-road accident, would turn amber to prevent traffic jams, while the nearest luminous road signs alert drivers to the situation, cameras capture the image of the road to reorganize traffic where necessary and city police automatically receive an alert [16].

Open Integrated Barcelona Barcelona *intends to integrate all the information* generated by smart services into a single Urban Platform in alliance with Cisco [31], through which it aims to achieve greater efficiency in information processing. The data of these services are currently gathered by sensors using different kinds of technology that do not communicate with one another. The city aim is to develop an urban operating system that integrates all the city's processing technologies into an interconnected network of information, which is generated by services such as mobility, safety, smart grids, and transport. The Urban Platform Reference Architecture can be connected easily and with a high degree of security across eight pilot tracks: transportation, real estate, safety and security, utilities, learning, health, sports and entertainment, and government [41]. Initial estimates from Cisco [31] and Barcelona City Council [16] suggest that the initiative has the potential to reduce the capital costs of telecommunications by up to 30%, with simultaneous operational savings of as much as 20–30%. In addition, it could reduce by as much as 25% the costs associated with introducing new city services as well as opening up new revenue channels for the city.

Advanced integration services are offered thanks to Europe's future Galileo satellite geo-positioning system. Location-based service based on Open Data to find the closest public bicycle stations, consult availability and location, station visualization in a map, interactive browsing through all the city, and direct access to preferred stations [20].

Barcelona Applications Smart city applications in Barcelona are at initial phase of implementation. The city mirrors the real-time city operation pulse as a system with systems capitalizing on smart resources to produce intelligence through applications such as [17]:

- Google Transit: offers planning services for journeys on public transport in the metropolitan area and consults users on mobile phone. It also finds routes between two points, offering several various options, and provides information on operators, journey times, timetables and routes, and real-time information on incidents, public works, and traffic density.
- TMB Virtual will locate all of the closest bus stops, metro stations, trams, and trains based on augmented reality. Virtual Touristic Bus provides information on the three Barcelona Bus Turístic service lines, with a description of each stop and all the points of interest along each of the routes.

- IRIS: fix my street on iPhone users will send images of their queries with their mobile phones. Traffic status provide information on current traffic, expected traffic in 15 min, traveling times, maps updated every 5 min, real-time images from street cameras.

Innovating Barcelona The city's most important outcome is the generation of *new business models for urban innovation* creating opportunities for *smart growth*. An Innovation Center which, according to the Mayor, Jordi Hereu, will be the equivalent of a "smart city laboratory" is a great example of public–private cooperation [17]. The City Council will accordingly establish the city infrastructures and expertise in service management and daily business while Cisco [31] will provide the researchers and the technology. The city is becoming an urban laboratory to perform field trials in the last phase of product development, to test of new products and services with urban impact in Barcelona as Smart City [18]. The aim of the Innovation Center would be to help create long-term economic growth and jobs through high-tech innovation and entrepreneurship. The Cisco Innovation Center would be underpinned by state-of-the-art networked collaboration technologies linking Barcelona to other innovation and technology centers around the world [17].

Barcelona's Media and ICT center [18], the business incubator, the Nord Technology Park, the technology transfer center, the showroom of new technologies, the smart energy and building efficiency center and the Cibernarium training center are important constituents of the city's innovation ecosystem. As an example of a triple helix exercise, the TIC Cluster has been created in order to boost the ICT sector competitiveness.

22@Barcelona project transforms 200 ha of industrial land of Poblenou into an innovative district offering modern spaces for the strategic concentration of intensive knowledge-based activities. This initiative is also a project of urban refurbishment and a new model of city providing a response to the challenges posed by the knowledge-based society. It is the most important project of innovative urban transformation in the Barcelona city area and one of the most ambitious in Europe with a 180 million Euros public investment [18].

Amsterdam: A Targeted-Layer Structure

Amsterdam Smart City is an urban innovation ecosystem that gathers companies, authorities, and living labs [13] with the support of the City of Amsterdam. It follows a bottom up participatory planning approach integrating broadband economies and intelligent applications (layers 2, 3, 4, and 5), green layer (1), and innovative (layer 6) into a targeted smart city vision for design and development of a sustainable, economically viable program to reduce the city's carbon footprint. The city offers the possibility to test these local initiatives and select the most effective initiatives that can then be implemented and introduced on a large scale.

Digital Amsterdam aims at 40% CO_2 reduction and 25% energy reduction by 2035 based on renewable energy and mobility initiatives. Amsterdam's City Council is implementing a city-wide fibber-to-the-home network, eventually connecting all 400,000 homes in the Dutch interconnected capital. Some parts of the city are

instrumented with smart energy meters and smart electric chargers that provide feedback for energy consumption. The smart city individual projects are integrated using a smart grid and the EcoMaP platform [14]. Sustainable living [13] projects provide heating and energy feedback to 500 households each. Sustainable mobility ship to grid provides 160 shore power connections to ships savings CO_2 emissions and noise. Smart schools and sustainable public space are examples of applications that change the behavioral mode of inhabitants. Innovating Amsterdam attempts to capitalize on smart city resources through concepts like Onze Energy, a people's financing project of seven wind mills, in return to low energy cost [14, 49].

While Barcelona follows a comprehensive top–down smart city master plan, orchestrated by the city council, Amsterdam is building its smart vision based on community grassroots initiatives and bottom up participation which ensures the important element of socially inclusive planning [49]. The city is collating a smart city plan based on the development of urban innovation ecosystem along the green, interconnected, instrumented, application, and innovation layers. In Smart Amsterdam, at the moment, 14 projects are financed by the European Regional Development Fund, local government, and local utility companies. Although each one of the projects is important to the city, there is a risk imposed in the expansion phase of successful pilots to larger scale projects. In Amsterdam smart fragments are raising important viability issues in relation to the ability of stakeholders and living labs to puzzle a convincing smart master plan [14, 49].

Edinburgh: A Limited-Layer Structure

The city is the center for education, tourism, and high-technology sector. The enterprise and innovation team take forward the Council's aims to support a prosperous and inclusive economy by supporting business and encouraging innovation with programs such as the Business Improvement Districts [50], where local businesses see the opportunity to invest collectively to help make local improvements. The city presents an impressive innovation ecosystem providing to the council the potential to promote the smart city vision. Despite these favorable conditions, the innovation ecosystem has not managed to respond to global urban challenges. The arbitrary announcement of Edinburgh as a smart city [50] is based only on an e-government initiative, generating a misconception of what is a smart city. Edinburgh's city council digital libraries are playing a key role in city regeneration, digital inclusion, and economic development [51].

Although the city enjoys the benefits of a dynamic renewable energy sector, the city has not managed to originate the appropriate public–private partnerships to employ the city's terrain as a test bed for these technologies. Even though there is wide broadband coverage by private providers, the city has not yet applied any inclusive or free broadband economy practices.

Conclusions and Discussion

The paper explores all issues related to the smart city as a map depicting concepts that might be applied to green innovation, broadband economy, and innovative urban

ecosystems. It examines respectively all aspects of "smartness" within a city addressing a mix of planning priorities into a reference model. Thus, the paper suggests a holistic conception in building a smart city vision by elucidating the smart innovation ecosystem as assemblies of smart planning policies in each layer of the reference model.

It contributes to the research agenda engaging the city as the founding ground for smart cities. The city layer (0) is consistent with a city's urban resources, infrastructures, utilities, services, stakeholders, and innovation ecosystems including triple helix complexions. The innovative character of these ecosystems could not necessarily fit in to the "smart economy", until they reach the stage to develop new business models in layer (6) when they capitalize on the resources of layers (1) to (5). City's structures, utilities, and urban planning, form a terrain as the playfield, where readiness to smart city changes is exercised. Conclusively, the planning agenda for urban innovation ecosystems starts from the city's readiness to implement smart policies.

The paper raises an imperative discussion topic, whether smart city conceptions should be defined by structural characteristics and whether these characteristics could delimit a smart city's course of action. It argues that cities should shape their way into the smart vision, on the condition that certain urban innovation ecosystem elements anchor city's smart investments into a sustainable future. Since cities are facing global challenges at a local echelon, they are the most important particles for a sustainable smart planet. Therefore, city master planning should contain the innovative characteristics that contribute to a green, sustainable smart planet growth, which was the focal point of the reference model.

Smart city planners could use the reference model to define the conceptual layout of a smart city and describe the urban innovation characteristics for each one of the six city layers. As smart cities come in different shapes and sizes, this reference model should be tailored to local urban innovation character integrating all layers of the model. Smart city planners could formulate a six layer planning agenda based on the local features and priorities of a city. Thus, this conceptual smart city planning could be the founding documentation for a smart city master plan. The reference model as an assembly of various smart city notions can be used to evaluate its innovative capacity in identifying complementarities and inconsistencies in smart city master planning.

Additionally, the conceptual model could be also utilized to synchronize and optimize city's investments in green and broadband economies. It also provides a common understanding among smart city stakeholders of investment priorities. The investigation of critical city's resources that will contribute to its readiness to smart vision is a crucial preliminary planning step. The outcomes of this research could be utilized by smart city planners to prevent unsustainable investments and to build upon the socio-technical complementarities in the smart city course of action.

The course for future research steps toward the refinement of the smart innovation model into a "system in systems" model that will mirror in detail smart city processes. Following a systemic approach, the model should be adaptive as far as inputs, outputs, and processings to the local context of a smart city. Key performance indicators should be explored not only for sustainability but also competitiveness, employment generation, fight against poverty, social divides and more. Furthermore,

a process-oriented evaluation model could be developed based on systemic smart city performance that will rival existing smart city benchmarking schemas.

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