# Chapter 2
# The Rise of the Smart City

*After reading this chapter, the following questions will be able to be answered*:

- *How can the smart city be defined and conceptualized?*
- *What are the challenges for smart cities?*
- *How can city and smart city be classified?*
- *What is the roadmap for smart city evolution according to historical evidence from literature findings?*
- *What is the smart city architecture from a system point of view?*

## 2.1 Defining the Terms

There is no common consensus about what "*smart*" really means in the context of the information and communications technology (ICT) (Cellary 2013). Although this term has become fashionable, it is also broadly used as a synonym of almost anything considered to be modern and intelligent. *Smart*, in purely definitional terms, has many synonyms, including percipient, astute, shrewd, and quick (Gil-Garcia et al. 2014). Moreover, *smart* is synonymous to efficient, when it is linked to devices (Meijer and Bolivar 2016). The following concise vision of smartness can be considered to be quite broad: *A servant surrounded by servants, which may be a configuration of both humans and devices, from both public and private sectors*. While the word "servant" evokes images from aristocracy to slavery in the evolving smart ecosystems, a person or system will be surrounded by or embedded within "servant systems", which are the smart systems. Moreover, the term smart refers to *ideas and people that provide clever insights* but it has been adopted more recently in city planning through the cliché *smart growth* (Batty et al. 2012). Growth can be seen as city sprawl, population increase or local economic upgrade, while smart growth implies the achievement of greater city efficiency



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through coordinating the forces that lead to growth: transportation, land speculation, conservation, and economic development (Batty et al. 2012).

Similarly, it is not easy to locate a common definition for the term city, while most people can conceptualize it according to individual experiences. A city is considered as an urban area, which according the United Nations (2005) typically begins with a population density of 1500 people per square mile but it varies across countries. Cities range according to their agglomeration from *localities* or *villages* (e.g., Greenland and Iceland) of 200–1000 inhabitants; to *communities* (or communes) of 1000–2500 people (e.g., Africa), to *towns* or *places* (e.g., Canada) or *cantons* with more than 400 (e.g., Albania) and less than 10,000 inhabitants (e.g., Greece); to *cities* with a population over 10,000 and 1.5 million inhabitants; and *megacities* with a population that exceeds 1.5 million people. Some cities are also called *global* or *international* due to their impact that attracts inhabitants beyond the country or even from all over the world. Small and medium-sized cities compete for resources against larger and better-equipped ones, while they all have peers (e.g., cities with similar characteristics) (Angelidou 2014). Another indicative definition says that "*city is an urban community falling under a specific administrative boundary*" (ISO 2014a, b), which shows that a city needs some model of governance. Community *is a group of people with an arrangement of responsibilities, activities and relationships*" (ISO 2016). Moreover, "*a city is a system of systems with a unique history and set in a specific environmental and societal context. In order for it to flourish, all the key city actors need to work together, utilizing all of their resources, to overcome the challenges and grasp the opportunities that the city faces*" (ISO 2014b).

Beyond their size and impact, cities can be classified according to their urban development stage to *new* and *existing* (Angelidou 2014). Most well-known cities are existing ones, but it is important to locate some new constructions, which are built to serve particular housing or economic or strategic needs: Tianjin (China), Masdar City (Abu Dhabi-UAE), PlanIT Valley (Portugal), Skolkovo Innovation Center (Russia), Cyberport Hong Kong (China), Songdo International Business District (South Korea), Cyberjaya (Malaysia) and Aspern (Vienna) are all cities from scratch or more likely to be new districts-parts of existing cities.

Cities are conceptualized as complex adaptive systems, which are comprised of components that belong either to *physical* or to *social* spheres (Desouza and Flanery 2013): *physical components* concern physical resources (i.e. the ingredients) and processes (i.e. tools to handle and distribute the ingredients) within a city's boundaries or that the city interacts with. *Social components* represent the human elements that reside within a city permanently or those that flow into, and/or interact with a city (people, institutions and activities). According to this approach, a city can be conceived as a mega-platform that brings these components to bear in an organized fashion.

The above components are also called *hard* and *soft* facilities respectively (Angelidou 2014; Neirotti et al. 2014): hard concern—except from the natural environment—all types of tangible facilities (e.g., buildings, streets, networks, bridges etc.), while soft concern intangible resources (e.g., people, organizations, knowledge, wealth etc.).

## 2.2 What Is *Smart City*?

It would be normal for someone to consider that smart city comes up from the combination of the above definitions: *an urban space that is surrounded by or is embedded with "smart systems" or a city with ideas and people that provide clever insights*. Smart systems should not be limited to ICT-based ones, but intelligence can refer even to creative design or new organizations etc. In this regard, the "smartness" of a city *describes its ability to bring together all its resources, to effectively and seamlessly achieve the goals and fulfil the purposes it has set itself* (ISO 2014b). However, if someone seeks for a clear definition for smart city, he will fail to locate one and instead, he will retrieve many alternatives, which generate an ambiguous meaning.

After its initial appearance in late 1990s, smart city definition ranges (Anthopoulos and Fitsilis 2014; Albino and Dangelico 2015; Nam and Pardo 2011; Chourabi et al. 2012; Gil-Garcia et al. 2014, 2016; Meijer and Bolivar 2016) from *metropolitan-wide information and communications technology (ICT)-based environments*; to *various ICT adjectives that describe a city* (Churabi et al. 2012); to *smart energy consumption, transportation and other hard asset management* (Neirotti et al. 2014); to *the "smartness footprint" of a city, which is measured with capacity indexes* (people, economy, living, environment, mobility and governance) (Giffinger et al. 2007); to *large-scale living labs for innovation testing* (Komninos 2002); to *the ability of a city to attract human capital and to mobilize this human capital in collaborations between the various (organized and individual) actors through the use of ICT* (Meijer and Bolivar 2016); to *the political jurisdiction (e.g., a city, a town, a nation) where a smart government applies emerging technologies and innovation* (Gil-Garcia et al. 2014, 2015); to *cities that undertake actions towards innovation in management, technology, and policy, all of which entail risks and opportunities* (Gil-Garcia et al. 2016); and to *innovative solutions—not limited to but mainly based on the ICT—that improve urban everyday life and enhance local sustainability in terms of people, governance, economy, mobility, environment and living* (Anthopoulos and Reddick 2015); or even recently, to the differentiation of the terms digital and smart cities: *digital cities exploit the cyberspace while the smart cities the physical space* (Ishida 2017). Moreover, Cocchia (2014) summarizes various definitions and discovers shared features characterizing smart cities, *which concern the role of innovation and technology; environmental requirements; and social development*.

Beyond the above, the European Commission programs FP7-ICT and CIP ICT-PSP approaches smart city as a "*user-driven open innovation environment*" (Schaffers et al. 2011), where city is seen as a platform that enhances citizen engagement and their willing to "co-create". "Openness" is being conceptualized in terms to apply various forms of relationships between people, services, infrastructure and technology (Lee et al. 2014). Open public services facilitate the coordination of people's participatory "living-playing-working" activities, while open-service oriented business models work according to open industry standards (in terms of infrastructure and technology) (Lee et al. 2014). In this respect, open innovation systems promote high quality social interactions (e.g., within communities), which enhance citizen engagement and participatory decision making.

Finally, it is important to mention how standardization bodies—at least the international ones—define the smart city: the International Telecommunications Union (ITU) (2014a, b) emphasizes on ICT and considers a *smart sustainable city as an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects*. Similarly, the International Standards Organization (ISO) (2014b) recognizes smart city as *a new concept and a new model, which applies the new generation of information technologies, such as the internet of things, cloud computing, big data and space/geographical information integration, to facilitate the planning, construction, management and smart services of cities*. Moreover, it defines smart city objective to pursue: *convenience of the public services; delicacy of city management; livability of living environment; smartness of infrastructures; long-term effectiveness of network security*. Furthermore, the British Standards (BSI 2014) concerns the smart city as *the effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens*.

The author summarizes the above definitions to provide a new and quite "umbrella" definition to smart city: *the utilization of ICT and innovation by cities (new, existing or districts), as a means to sustain in economic, social and environmental terms and to address several challenges dealing with six (6) dimensions (people, economy, governance, mobility, environment and living)*. Depending on this ICT and innovation performance, as well as on the local priorities, each city performs differently and appears with alternative smart city forms.

Some of the smart city challenges have been already identified: *providing an economic base; building efficient urban infrastructure; improving the quality of life and place; ensuring social integration; conserving natural environmental qualities, and; guaranteeing good governance* (Yigitcanlar and Lee 2014). Moreover, these definitions demonstrate that scholars conceptualize smart city with alternative approaches. In this respect, Anthopoulos et al. (2016) performed a comparative analysis on existing smart city conceptual models (Table 2.1).

These models synthesize a smart city ecosystem, which consists of eight (8) components (Fig. 2.1) that establish a cyber-physical integration and—with the incorporation of standardization perspectives—concern:

1. **Smart infrastructure**: city facilities (e.g., water and energy networks, streets, buildings etc.) with embedded smart technology (e.g., sensors, smart grids etc.).
2. **Smart Transportation** (or smart mobility): transportation networks with enhanced embedded real time monitoring and control systems.

**Table 2.1** Smart city conceptual models (Anthopoulos et al. 2016)

| | Model | Description |
|---|---|---|
| *Architecture* | | |
| Anthopoulos (2015) | Smart city dimensions | Resource, transportation, urban infrastructure, living, government, economy, coherency |
| Giffinger et al. (2007) | Smart city components | Smart economy, smart governance, smart people, smart mobility, smart living, smart environment |
| Glebova et al. (2014) | Smart city conceptual elements | Intellectual transport system, public security, energy consumption management and control, environmental protection and ICT |
| Hancke et al. (2013) | Sensor areas in smart city | Smart infrastructure, smart surveillance, smart electricity and water distribution, smart buildings, smart healthcare, smart services and smart transportation |
| Hollands (2008) | Smart city model | Instrumented (based on data collection)<br>Interconnected (enable data flow)<br>Smart (utilize data to improve urban living) |
| IBM<br>Söderström et al. (2014) | Nine pillar models<br>smarter city equation | Planning and management services<br>Infrastructure services<br>Human services<br>Instrumentation (*the transformation of urban phenomena into data*) + Interconnection (*of data*) + Intelligence (*brought by software*) |
| Naphade et al. (2011) | Smart city model | Government services, transportation, energy and water, healthcare, education, public safety and other core ICT systems |
| Neirotti et al. (2014) | Smart city domains | Natural resources and energy, transport and mobility, buildings, living, government, economy and people |
| Yovanof and Hazapis (2009) | Digital city architectural framework for smart service provision | Infrastructure (communications); mobilized services (capability to mobilize data, applications and users); policy (legal framework to foster innovation) |
| Zygiaris (2012) | Smart city reference model | Multi-tier smart city model with several components and entities |

(continued)

**Table 2.1** (continued)

| | Model | Description |
|---|---|---|
| *Governance* | | |
| Albino and Dangelico (2015) | Smart city dimensions | – City's networked infrastructure that enables political efficiency and social and cultural development<br>– Emphasis on business-led urban development and creative activities for the promotion of urban growth<br>– Social inclusion of various urban residents and social capital in urban development<br>– The natural environment as a strategic component for the future |
| Baron (2012) | Three level-model for city intelligence for resilience conceptualization | First level of city smartness: Led by example<br>Second level of city smartness: govern the private urban actors<br>Third level of city smartness: integrated approach<br>(hi/medium/no resilience) |
| ISO (2014a, b) | A table of city characteristics where smartness is applied | Environmental context<br>City history and characteristics<br>Societal context<br>City governance<br>City subsystems (actors, activities, facilities and buildings, hard infrastructure, soft infrastructure, technical systems, city functions, scale) |
| ITU (2014a, b) | Attributes and core themes | Attributes: sustainability; quality of life; urban aspects; intelligence or smartness<br>Core themes: society; economy; environment; governance |
| Lee et al. (2014) | Framework for smart city analysis | Urban Openness, service innovation, partnerships formation, urban proactiveness, smart city infrastructure integration, smart city governance |
| Leydesdorff and Deakin (2011) | Triple-Helix model of smart cities | Networks of universities, industry and government |
| Liu et al. (2014) | Smart city value chain (SCVC) model | Primary activities: smart inbound logistics; smart operations; smart outbound logistics; smart marketing; smart services<br>Supportive activities: smart government; smart infrastructure; smart procurement; smart technology |

(continued)

**Table 2.1** (continued)

| | Model | Description |
|---|---|---|
| Lombardi et al. (2012) | Triple helix model for smart city analysis and performance measurement | A table with rows: university, government, civil society, industry and columns: smart governance, smart economy, smart people, living, environment |
| United Nations Habitat (2014) | Dimensions of city prosperity | Productivity and the prosperity of cities<br>Urban infrastructure: Bedrock of prosperity<br>Quality of life and urban prosperity<br>Equity and the prosperity of cities, environmental sustainability and the prosperity of cities |
| *Planning and management* | | |
| Anthopoulos and Fitsilis (2013) | Technology roadmapping for smart city development | Patterns for smart city technological evolution |
| Lee et al. (2013) | Technology Roadmapping for smart city development | Interconnections between services and devices, and between devices and technologies |
| *Data and knowledge* | | |
| Batty et al. (2012) | Structure of futurICTs smart city programme | Data analysis and modelling: mobility and transport behavior; urban land use transport; urban market transactions; urban supply chains<br>Infrastructure: sensing and networks, new social media; integrated databases<br>Management: decision support and participation; city governance |
| Bellini et al. (2014) | Knowledge model for smart city data (KM4City ontology) | Administration; street-guide; point-of interest; local public transport; Sensors; temporal; and metadata |
| Edvinsson (2006) | City as a knowledge tool model | Knowledge key driver definition and interrelation discovery<br>(ICT and multimedia; university; society and entrepreneurship; knowledge cafes/cathedrals; diversity; strange attractors) |
| *Facilities* | | |
| Calvillo et al. (2016) | Smart city energy interventions and energy system design model | Energy interventions areas: Generation, storage, infrastructure, facilities and transport<br>Energy system design model:<br>(i) System input (resources, costs, geolocation, energy prices, regulation, demand)<br>(ii) System output (capacity, total production, costs, environmental benefits, viability) |

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**Table 2.1** (continued)

| | Model | Description |
|---|---|---|
| *Services* | | |
| Fan et al. (2016) | Smart health organization model | Multi-tier architecture for smart health service production in smart city |
| *People* | | |
| Shapiro (2006) | Neoclassical city growth model | Employment growth sources: Productivity, quality of life |
| Thite (2011) | Urban factors for human capital attractiveness | *Magnets* (a healthy and well-educated workforce, clean environment, vibrant business climate, and a solid social and cultural infrastructure) and *glue* (city infrastructure, flexible regulation system) |
| *Environment* | | |
| Shwayri (2013) | U-eco-city model | City as a range of ubiquitous services (including u-health, u-education, u-transport and u-government) |
| Tsolakis and Anthopoulos (2015) | Eco-city System Dynamics Model | A system of 5 interconnected components/subsystems: (i) population, (ii) housing, (iii) business, (iv) energy and (v) environmental pollution |

3. **Smart Environment**: innovation and ICT incorporation for natural resource protection and management (waste management systems, emission control, recycling, sensors for pollution monitoring etc.).
4. **Smart Services**: utilization of technology and ICT for health, education, tourism, safety, response control (surveillance) etc. service provision across the entire city.
5. **Smart Governance**: smart government establishment in the urban space, accompanied by technology for service delivery, participation and engagement.
6. **Smart People**: measures that enhance people creativity and open innovation.
7. **Smart Living**: innovation for enhancing quality of life and livability in the urban space.
8. **Smart Economy**: technology and innovation for strengthening business development, employment and urban growth.

These components are interconnected and require data collection and ICT infrastructure, to be embedded within city hard infrastructure to deliver smart services to city actors, while governance is necessary in order for the subsystems to be orchestrated and succeed in smart city mission (Fig. 2.2).

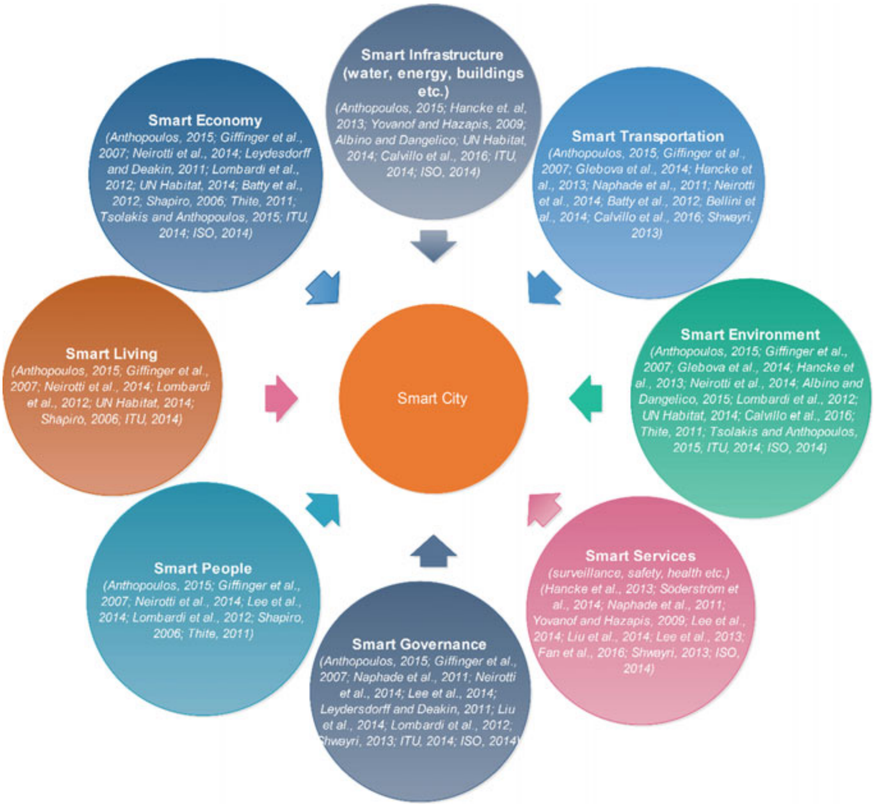


**Fig. 2.1** Smart city components

## 2.3 The Smart City Evolution

The smart city concept started appearing in time with different terms and perspectives as a means to define urban technological evolution. More specifically, smart city was not the initial term that was used by scholars. Instead, scholars in late 1990s started discussing about city and ICT from different perspectives and with the use of different terms, in their attempts to describe ICT project initiation within the urban space or the utilization of the ICT to treat local needs (Fig. 2.3).

First evidence regarding smart city appears in literature in 1997 (Graham and Aurigi 1997), where it is claimed that over 2000 virtual cities and urban web pages existed in 1997, which introduced the term ***web*** or ***virtual city*** in an attempt to describe local ICT network initiatives, which enabled the development of local cyber-based (virtual) communities (decentralized, interactive, one-to-one and one-to-many media networks). Virtual cities were based on the World Wide Web (WWW) and they operated as electronic analogies for the real, material, urban areas that host them. The promise of virtual cities was to develop new interactive

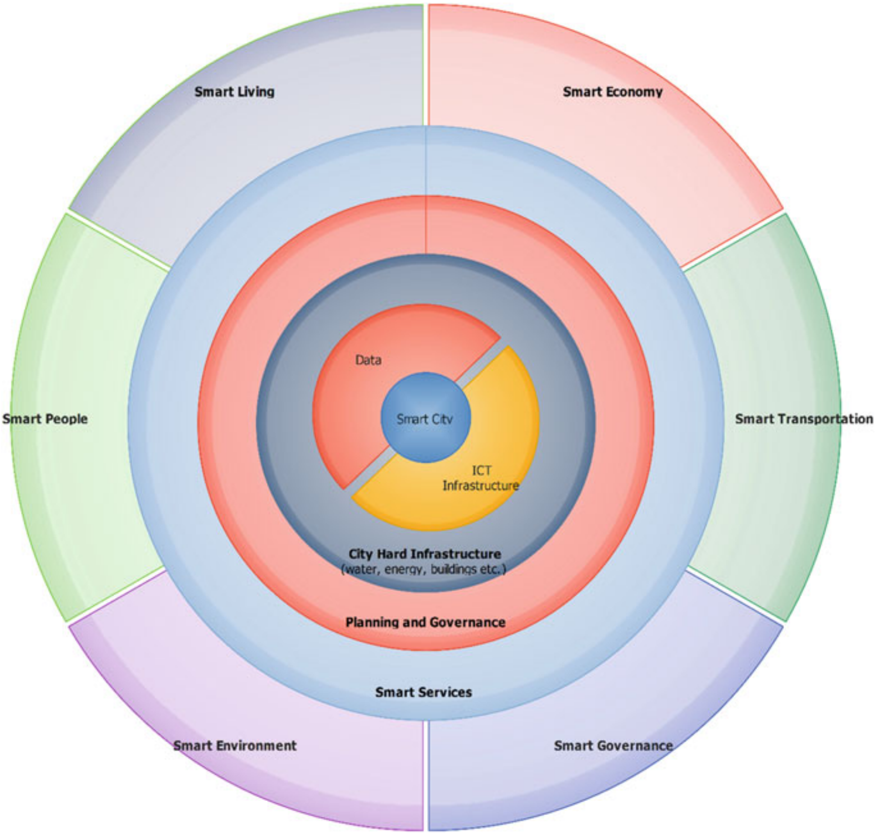


**Fig. 2.2** Smart city conceptual system

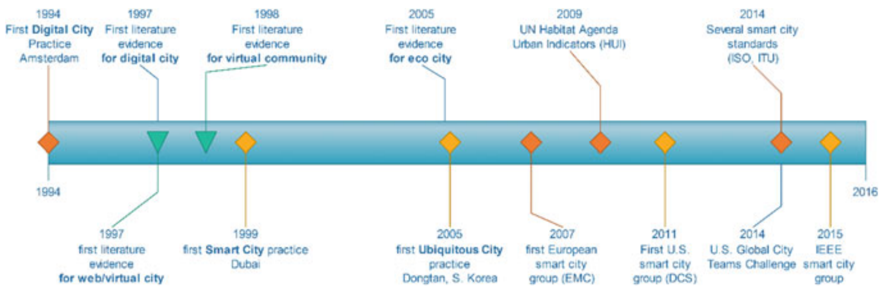


**Fig. 2.3** Smart city evolution timeline

"public-arenas", especially in cities where the lack of public space, the growing violence, fear alienation and the reduction in civic associations do not enable public interaction, but instead they enhance "urban privatism". Web or Virtual cities drew together all web activities in a city or simulated a city on the web and they were configured as little more than urban databases that provided public information for the municipal authorities to even transport and leisure data, cultural events and tourist guides. Virtual cities concerned the first attempt that utilized the potential of the Internet for supporting local democracy and enabled urban marketing, new types of electronic municipal service delivery, local inter-firm networking, and social and community development within cities. However, an absence of citizens was documented, whose feedback was supposed to be necessary to establish.

The same work (Graham and Aurigi 1997) introduced the term ***digital city*** too, which was a more socially inclusive and discourse driven virtual city. In this respect, the first forms of digital cities included thematic spaces for citizen interactions. Digital city was mentioned in the second work, only a year later by van den Besselaar and Beckers (1998), who named the term as a large infrastructure for virtual communities. Communities concern associations between people, which are coordinated through communication based on shared norms and interests. The above definition demonstrates that digital city is a broader term, compared to community networks, since digital city's scope is wider (it is not focused on a specific urban space) and it can deliver services to non-community members that would like to register them. Moreover, this work mentioned the Internet-enabled community structure that exceeds the physical space, which limits locality. Instead, local communities are the ones that share common interests (special interest groups). The first digital city practice was implemented in Amsterdam[1] in 1994 as the result from an activists' effort, with the aim to enable dialogue between community and politicians. It was a success story since the citizens adopted progressively the effort, while it was accompanied by the implication of stimulating Internet penetration in the city.

The above evidence shows that both *virtual* and *digital* smart city types initiated an approach to handle similar challenges with similar technological means: they aimed to create communities with the use of the ICT in an attempt to socialize inhabitants, to democratize local governments and to utilize virtual places against the lack of public space. In this respect, the Internet, combined with urban network infrastructure and the WWW were used to develop city websites, which offered alternative smart services mainly regarding *information retrieval* (e.g., city guides, information for transportation, government political information's and forms' sharing, employment opportunities etc.), *synchronous* (chatting, debates and gaming) and *asynchronous communication* (e-mail, discussion groups and billboards). These two initial smart city approaches simulated the urban space either as connected islands of communities (community of communities) or even as two-dimension (2D) or three-dimension (3D) virtual spaces. From organization point of view, both these two types started as bottom-up initiatives from users that shared common interests, but by 1997 they evolved to not-for-profit organizations with turnovers (e.g., the Amsterdam digital city of about $0.5 US million in 1997

[1]Amsterdam digital city or DDS (De Digitale Stad, Dutch for The Digital City).

and 25 employees) led by municipalities. Another famous digital city case was Kyoto (Ishida 2017), which was launched in 1998 and resulted to 2D and 3D spaces, where citizen interactions could be collected with sensors (cameras) and reproduce with animation their behavior.

The *digital city* concept became synonymous to ***information city***, which was understood as a metropolitan environment where the ICT is the key driver in delivering innovative online services (Lee et al. 2014). The notion of *digital* or *information* city was later evolved to the ***ubiquitous city*** where data is ubiquitously available through an embedded urban infrastructure (e.g., through equipment embedded in streets and other urban hard facilities) (Anthopoulos and Fitsilis 2014). The term originates from the South Korean government, who refer to "a city that is managed by the network and provides … citizens with services and contents via the network … with a BUCI (fixed u-City infrastructure) and MUCI (mobile u-City infrastructure), built on high-end technologies such as sensors" (Lee et al. 2014). Another term which is also being discussed is the ***intelligent city***, which focuses on the city performance regarding producing innovation in the following three dimensions: (1) Intelligence, inventiveness and creativity; (2) Collective intelligence and (3) Artificial intelligence (Lee et al. 2014).

The above smart city types evolved steadily to more "sophisticated" ecosystems, which are able to offer more intelligent services and enable technological embeddedness. Anttiroiko et al. (2014) explain *technological embeddedness* as the ability of technology to embed in social systems in order to achieve in smart service delivery. Level of embeddedness ranges from simple information delivery (low), which increases to intelligent system implementation (functionality), then to systems that deal with social and human concerns (quality of life) and to ecological systems (sustainability) (Anttiroiko et al. 2014). *Ecosystems* on the other hand, are generally defined as communities of interacting organisms and their environments, and are typically described as complex networks formed because of resource interdependencies (Gretzel et al. 2015). An ecosystem can be seen as "an interdependent social system of actors, organizations, material infrastructures, and symbolic resources" (Maheshwari and Janssen 2014). In this respect, ecosystems, like other kinds of systems, are comprised of elements, interconnections and a function/purpose, but are special types of systems in that their elements are intelligent, autonomous, adaptive agents that often form communities and also because of the way they adapt to elements being added or removed. According to this definition, four critical elements exist in ecosystems: (1) interaction/engagement; (2) balance; (3) loosely coupled actors with shared goals; and, (4) self-organization (Gretzel et al. 2015).

Today, almost all cities claim to be more or less smart with an underlying self-congratulatory tendency (Hollands 2008), obviously with regard to a different level of technological embeddedness or due to the existing intelligent capacity that a city holds. In an attempt to overcome this self-congratulatory "smart labeling", scholars like Hollands (2008) have emphasized on the existence of embedded ICT (interconnected, instrumented and smart) that enable data flow, while others—e.g., the ones compared by Anthopoulos et al. (2016)—have developed benchmarking

**Table 2.2** Smart city coalitions and groups of study

| | Coalition/group | Description—source | Year | Scope |
|---|---|---|---|---|
| 1. | Innovation Cities$^{TM}$ (IC) | 2thinknow (www.2thinknow.com) | 2011 | Global (330 cities) |
| 2. | Eurocities | Network of major European cities (http://www.eurocities.eu) | 1986 | Europe (130 European largest cities from 35 countries) |
| 3. | Smart Cities—European Medium Sized Cities (EMC) | Three European university-based research centers[a] (http://smart-cities.eu/) | 2007 | Europe |
| 4. | Market Place of the European Innovation Partnership (EIP) on smart cities and communities | Initiative supported by the European Commission bringing together smart city actors (https://eu-smartcities.eu) | 2011 | Europe (4000 partners from 31 countries) |
| 5. | E-Forum | Not-for-profit association active in e-government, e-Identity and EU-China Smart City development (www.eu-forum.org) | 2001 | Europe |
| 6. | Green Digital Charter | Commits cities to reduce emissions through ICT and promote progress in tackling climate change through the innovative use of digital technologies in cities. Works under Eurocities (http://www.greendigitalcharter.eu/) | 2009 | Europe (cities from 21 countries) |
| 7. | Global Cities Dialogue on Information Society (GCD) | Non-profit international association of Mayors and High Political Representatives (http://globalcitiesdialogue.com/) | 1999 | Global (over 200 cities) |
| 8. | Digital Cities Survey (DCS) | Center for Digital Government (www.centerdigitalgov.com/) | 2011 | U.S.A. |
| 9. | UN-Habitat Agenda Urban Indicators (HUI) | UN Habitat[b] | 2009 | Global |
| 10. | Smarter City Assessment Model (IBM model) | IBM[c] | 2009 | General |
| 11. | IEEE Core Smart Cities | IEEE[d] | 2015 | Global (5 core cities and 7 affiliated) |

(continued)

**Table 2.2** (continued)

| | Coalition/group | Description—source | Year | Scope |
|---|---|---|---|---|
| 12. | City Resilience Profiling Programme (CRPP) | UN Habitat (https://www.cityresilience.org/CRPP) | 2012 | Global (10 cities) |
| 13. | Alcatel-Lucent smart city analysis | Alcatel-Lucent[e] | 2012 | Global (52 cities) |
| 14. | Global City Teams Challenge | U.S. National Institute of Standards and Technology, US-Ignite (http://www.nist.gov/cps/sagc.cfm) | 2014 | U.S.A. |
| 15. | MIT Media Lab Cities Network | MIT Media Lab (http://cities.media.mit.edu/living-labs/) | 2014 | Global (3 cities) |
| 16. | Smart Cities Council | Smart Cities Council is an advisor and market accelerator (http://smartcitiescouncil.com/) | 2012 | Global |
| 17. | Smart to Future Cities | Ovum TMT Intelligence, Informa (https://smarttofuture.com/) | 2014 | UK, Global |
| 18. | City Protocol | Collaborative innovation framework (http://cityprotocol.org/) | 2015 | Global |
| 19. | The Open and Agile Smart Cities (OASC) Initiative | City-driven, non-profit organization (http://oascities.org) | 2015 | Global |
| 20. | International Council for Local Environmental Initiatives (ICLEI) | ICLEI smart city[f] | 2016 | Global |
| 21. | World Council on City Data (WCCD) | Global leader in standardized city data (http://www.dataforcities.org/) | 2014 | Global |
| 22. | Global Cities Institute (GCI) | At the University of Toronto (http://www.globalcitiesinstitute.org/) | 2008 | Global (255 cities, 82 countries) |
| 23. | The Global City Indicators Facility | Program of the Global Cities Institute (http://cityindicators.org/) | 2008 | Global |
| 24. | CITYNET | City network in the Asia Pacific with the support of United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), the United Nations Centre for Human Settlements (http://citynet-ap.org/) | 1987 | Asia Pacific |

(continued)

**Table 2.2** (continued)

| | Coalition/group | Description—source | Year | Scope |
|---|---|---|---|---|
| 25. | Cities Alliance | Global partnership for urban poverty reduction and the promotion of the role of cities in sustainable development (http://www.citiesalliance.org/) | 1999 | Global |
| 26. | United Cities and Local Governments (UCLG) | Represents and defends the interests of local governments on the world stage (https://www.uclg.org) | 2004 | Global (more than 1000 cities from 95 countries) |
| 27. | The World Association of Major Metropolises (Metropolis) | An international association of global cities working towards developing solutions to issues affecting large cities. It serves UCLG (http://www.metropolis.org/) | 1985 | Global (137 global cities) |
| 28. | The Council of Local Authorities for International Relations (CLAIR) | A joint organization made up of local governments (http://www.clair.or.jp/e/) | 1988 | Japan |
| 29. | Centre for Liveable Cities (CLC) Singapore | With the support of the Ministry of National Development and the Ministry of the Environment and Water Resources (http://www.clc.gov.sg/) | 2008 | Singapore |
| 30. | C40 Cities Climate Leadership Group (C40) | C40 is a network of the world's megacities committed to addressing climate change (http://www.c40.org/) | 2006 | Global (80 of the world's greatest cities) |
| 31. | World Resources Institute (WRI) Ross Center for Sustainable Cities | Global research and on-the-ground experience for urban sustainability (http://www.wrirosscities.org/) | 2014 | Global |
| 32. | Coalition for Urban Transitions | International initiative to enhance national economic, social, and environmental performance, including reducing the risk of climate change (hosted at WRI) (http://www.coalitionforurbantransitions.org/) | 2013 | Global |

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**Table 2.2** (continued)

| | Coalition/group | Description—source | Year | Scope |
|---|---|---|---|---|
| 33. | The International Society of City and Regional Planners (ISOCARP) | Global association of experienced professional planners, recognized by UN, UNHCS and Council of Europe (http://isocarp.org/) | 1965 | Global |
| 34. | World e-Governments Organization of Cities and Local Governments (WeGO) | International cooperative body of cities and local governments that pursues sustainable city development based on e-Government (http://www.we-gov.org/) | 2008 | Global (97 Cities) |
| 35. | Energy Services Network Association (ESNA) | Independent global, not-for-profit association under Dutch law. Members share the same goal and vision and are utilities, software, hardware and service providers, and solution integrators (http://www.esna.org/) | 2006 | Global (32 companies) |
| 36. | 6Aika or the Six City Strategy | A cooperation strategy between the six largest cities in Finland (Helsinki, Espoo, Vantaa, Tampere, Turku, and Oulu), with regard to generate new expertise, business operations, and jobs and focus on open innovation platforms, open data and interfaces, and open participation (http://6aika.fi/) | 2014 | Finland (6 cities) |
| 37. | Internet of Things Council | Thinktank for the Internet of Things (http://www.theinternetofthings.eu/) | 2009 | Europe |
| 38. | Sister Cities International | Nonprofit organization, which serves as the U.S. membership organization for individual sister cities, counties, and states (http://sistercities.org/) | 1956 | U.S./Global (570 member communities) |

(continued)

**Table 2.2** (continued)

| | Coalition/group | Description—source | Year | Scope |
|---|---|---|---|---|
| 39. | Alberta Smart City Alliance | Cross-sector collaboration between community leaders and city builders, forward-thinking governments, corporations, entrepreneurs, and academic innovators (https://smartcityalliance.ca) | 2014 | Canada (110 members with 12 cities and 30 towns) |
| 40. | Asian Cities Climate Change Resilience Network (ACCCRN) | Comprises practitioners and institutions committed—under the Rockefeller Foundation—to creating knowledge, accessing resources, and influencing agendas to build inclusive urban climate change resilience (http://acccrn.net/) | 2008 | Asia (50 cities) |
| 41. | Smart Cities Smart Government Research-Practice (SCSGRP) Consortium | Global Smart Cities research community that focuses on innovations in technology, management and policy that change the fabric of the world's cities (https://www.ctg.albany.edu/projects/smartcitiesconsortium) | 2012 | Global (at the University of Albany) |
| 42. | Open and Agile Smart Cities (OASC) | City-driven, non-profit organization. (http://www.oascities.org/) | 2015 | Global (more than 30 cities) |

[a]The Center of Regional Science at Vienna University of Technology, the Department of Geography at the University of Ljubljana, and Research University of Housing, Urban and Mobility Studies at Delft University of Technology
[b]www.unhabitat.org/downloads/docs/Urban_Indicators.pdf
[c]http://www.ibm.com/smarterplanet/us/en/smarter_cities/overview/
[d]http://smartcities.ieee.org/home/core-cities.html
[e]http://www.tmcnet.com/tmc/whitepapers/documents/whitepapers/2013/6764-getting-smart-smart-cities-market-analysis.pdf
[f]http://www.iclei.org/activities/agendas/smart-city.html

models for smart city to measure corresponding progress or existing capacity. Moreover, the above conceptualization models have been utilized by many smart city cases, recent studies have been employed by many smart city coalitions, while more than 300 smart cities are mentioned by studies and business reports (Table 2.2).

## 2.4 City and Smart City Classes

Several city classes were presented in the previous sections, which aggregate cities according to their *population and density* (village, community, town, city and megacity), to their *impact* (local and global cities) and to their *development stage* (new and existing cities).

On the other hand, the extreme smart city growth that has been performed during the last 20 years has created various alternative smart city types. For a beginning, Alcatel-Lucent (2012) classify smart cities in market-driven groups: “GreenFields” and “Brownfields” that display the size (large-scale cases compared to small-scale ones) of the smart city project; and to four different “box” types according to project organization and business model:

- *Information Technology (IT) box*: a private company initiates the smart city and private funding business model;
- *Dream box*: public-private partnership (PPP) for project definition and respective business model;
- *Fragmented box*: many projects initiated by various stakeholders with little or no integration; and
- *Black box*: initiated and managed by (local, state or national) Governments or public agencies, with “invited” companies to enter this ecosystem.

Additionally, Anthopoulos and Fitsilis (2014) made an analysis of 34 different smart cities and discovered alternatives that vary with regard to the ICT that has been embedded within the city and defines an alternative smart adjective to city. These alternatives determine several smart city classes, which range and mainly address the adjective that describes the particular ICT that is installed in the city. More specifically, the following classes can be located Anthopoulos and Fitsilis (2014) (Table 2.3):

- *Web or Virtual Cities*: offer local information, online chatting and meeting rooms, and city augmented reality navigation via the Web. Some indicative cases concern: America-On-Line (AOL) Cities (1997), Kyoto, Japan (1998–2001), Bristol, U.S.A. (1997) and Amsterdam (1997).
- *Knowledge Bases* (van Bastelaer 1998) or *Knowledge Cities:* are digital public repositories with crowd sourcing options accessible via the Internet and via text-TV (Copenhagen Base (1989); Craigmillar Community Information Service, Scotland (1994); and Blacksburg Knowledge Democracy). Later approaches by Edvinsson (2006), Yigitcanlar et al. (2008) define knowledge city as locally focused innovation, science and creativity within the context of an expanding knowledge economy and society. This later approach has been followed by Melbourne.
- *Broadband City/Broadband Metropolis*: describe fiber optic backbones in the urban area, which enable the interconnection of households and of local enterprises to ultra-high speed networks. Seoul, S. Korea (1997); Beijing, China (1999); Helsinki (1995); Geneva-MAN, Switzerland (1994) (van Bastelaer 1998); and Antwerp comprised this category.

**Table 2.3** Smart city classes and representatives (Anthopoulos and Fitsilis 2014)

| Category | Representatives and year of their appearance | Explanation/current state |
|---|---|---|
| Web/Virtual City | 1. **America-On-Line (AOL) Cities** (1997)<br>2. **Kyoto**, Japan (1996–2001) http://www.digitalcity.gr.jp<br>3. **Bristol, U.S.A.** (1997)<br>4. **Amsterdam** (1997) | 1. **America-On-Line (AOL) Cities** City Guides for U.S. cities http://www.citysbest.com<br>3. **Bristol, U.S.A.** http://www.digitalbristol.org/<br>6. **Craigmillar Community Information Service** Scotland http://www.s1craigmillar.com |
| Knowledge Bases | 5. **Copenhagen Base** (1989)<br>6. **Craigmillar Community Information Service**, Scotland (1994)<br>7. **Blacksburg Knowledge Democracy**, U.S.A. (1994) | |
| Broadband City/Broadband Metropolis | 8. **Seoul**, S. Korea (1997)<br>9. **Beijing**, China (1999)<br>10. **Helsinki** (1995)<br>11. **Geneva-MAN**, Switzerland (1994)<br>12. **Antwerp**, Belgium (1995) | 11. **Geneva-MAN**, Switzerland |
| Wireless/Mobile City | 13. **New York** (1994)<br>14. **Kista Science City/Stockholm** (2002)<br>15. **Florence**, Italy (2006) | 13. **New York** http://www.nyc.gov/html/doitt/<br>14. **Kista Science City/Stockholm** http://en.kista.com<br>15. **Florence**, Italy http://senseable.mit.edu/florence/ |
| Smart City | 16. **Taipei**, Taiwan (2004)<br>17. **Tianjin**, China (2007)<br>18. **Barcelona**, Spain (2000)<br>19. **Brisbane**, Australia (2004)<br>20. **Malta** (2007)<br>21. **Dubai** (1999—today)<br>22. **Kochi**, India (2007) | 10. **Helsinki** http://www.hel.fi<br>12. **Antwerp**, Belgium Evolved from Broadband City; it is interconnected to Brussels and to Amsterdam; offers its infrastructure with the open access business model; it operates under the Municipality and invites private investments<br>19. **Brisbane**, Australia http://www.brisbane.qld.gov.au<br>20. **Malta** http://malta.smartcity.ae/<br>21. **Dubai** www.dubaiinternetcity.com, www.dubaimediacity.com<br>22. **Kochi**, India http://www.smartcity.ae |

(continued)

**Table 2.3** (continued)

| Category | Representatives and year of their appearance | Explanation/current state |
|---|---|---|
| Digital City | 23. **Hull**, U.K. (2000)<br>24. **Cape Town**, South Africa (2000)<br>25. **Trikala**, Greece (2003)<br>26. **Tampere**, Finland (2003)<br>27. **Knowledge Based Cities**, Portugal (1995)<br>28. **Austin**, U.S.A. (1995—today) | 9. **Beijing**, China<br>It evolved from a broadband city<br>7. **Blacksburg Electronic Village**, U.S.A.<br>It updated its mission and evolved from a knowledge base<br>http://www.bev.net/<br>23. **Hull**, U.K.<br>http://www.hullcc.gov.uk<br>24. **Cape Town**, South Africa<br>http://www.capetown.gov.za<br>25. **Trikala**, Greece<br>Exists and limited its scope to tele-care and to metro-Wi-Fi services<br>www.e-trikala.gr<br>26. **Tampere**, Finland<br>It began as a thinking tank for innovative ICT applications. Today it occupies more than 1000 professionals who develop various e-Services<br>http://www.tampere.fi<br>27. **Knowledge Based Cities**, Portugal<br>Portals of the digital cities have not met projects' objectives<br>http://www.cidadesdigitais.pt |
| Ubiquitous City | 29. **New Songdo**, S. Korea (2008)<br>30. **Dongtan**, S. Korea (2005)<br>31. **Osaka**, Japan (2008)<br>32. **Manhattan Harbour, Kentucky**, U.S.A. (2010)<br>33. **Masdar**, United Arab Emirates (2008)<br>34. **Helsinki Arabianranta**, Finland (2005) | 8. **Seoul**, S. Korea<br>Evolved from a broadband city and operates under a coalition of public and private stakeholders (Korean Ministry of Information and Communications, 2007)<br>29. **New Songdo**, S. Korea<br>http://www.songdo.com<br>31. **Osaka**, Japan<br>http://www.osakacity.or.jp<br>32. **Manhattan Harbour, Kentucky**, U.S.A.<br>http://www.manhattanharbour.com<br>34. **Helsinki Arabianranta**, Finland<br>Operated as a living lab<br>http://www.arabianranta.fi/ |

(continued)

**Table 2.3** (continued)

| Category | Representatives and year of their appearance | Explanation/current state |
|---|---|---|
| Eco City | | 4. **Amsterdam**<br>It evolved to other approaches (broadband, smart, eco-city)<br>http://www.amsterdamsmartcity.com<br>5. **Copenhagen**<br>It has evolved from a knowledge base<br>http://www.kk.dk<br>16. **Taipei**, Taiwan<br>It has evolved from a Smart City<br>http://english.taipei.gov.tw/<br>17. **Tianjin (Singapore)**,<br>Public housing project in the Eco-city and Keppel District Heating and Cooling System Plant<br>http://www.tianjinecocity.gov.sg<br>18. **Barcelona**, Spain<br>Evolved from a Smart City<br>http://w3.bcn.es, http://www.bcn.es<br>28. **Austin**, U.S.A.<br>It began as a digital city and emerged to Eco City<br>http://www.cityofaustin.org/<br>33. **Masdar**, United Arab Emirates<br>Evolved from a ubiquitous city<br>http://www.masdarcity.ae<br>30. **Dongtan** S. Korea<br>Evolved from a ubiquitous city |

- *Mobile/Wireless/Ambient Cities* are wireless broadband networks accessible across the city or in some districts. New York City (1994); Kista Science City/Stockholm (2002) and Florence, Italy (2006) were the identified representative members.
- *The Digital or Information City* describes an ICT environment across the city that is built to deal with: (a) local needs and transactions, (b) the transformation of the local community to a local information society, and (c) sustainable local development. Hull, U.K. (2000); Cape Town, South Africa (2000); Trikala, Greece (2003); Tampere, Finland (2003); Knowledge Based Cities, Portugal (1995); and Austin, U.S.A. (1995—today) are members of this group.
- *The Ubiquitous City* extends the digital or information city in enabling ubiquitous service provision and data flow from anywhere to everyone. New Songdo, S. Korea (2008); Dongtan, S. Korea (2005); Osaka, Japan (2008); Manhattan Harbour, Kentucky, U.S.A. (2010); Masdar, United Arab Emirates (2008); and Helsinki Arabianranta, Finland (2005) are some representatives.
- *The smart city* came to extend ubiquitous city in a sense that emphasized social infrastructure (human and social capital, named the dimension of *people*) of the

city (Lee et al. 2014). This approach offers broadband and media infrastructures for business growth too. Taipei, Taiwan (2004); Tianjin, China (2007); Barcelona, Spain (2000); Brisbane, Australia (2004); Malta (2007); Kochi, India (2007); and Dubai (1999—today) were labeled "smart" from their initial appearance.

- Finally, the *Eco City* extends ubiquitous city with a service agenda that respects the physical landscape of the city or in other words it capitalizes the ICT for sustainable growth and for environmental protection.

As it can be seen on (Table 2.3), many members of the above classes did not remain in a specific group but shifted from a class to another, even more than once. In an attempt to recognize whether these changes suggest a technological evolution or patterns of change, Anthopoulos and Fitsilis (2013) performed an analysis of the types of smart services that 29 of the above cases offer and structured nine (9) smart service groups (SG), inspired by (Alcatel-Lucent 2012) market-driven groups:

- *SG1: e-Government services* (City Administration market-driven group) concern typical public transactions (offered by digital, smart and ubiquitous city classes).
- *SG2: e-democracy services* (City Administration market-driven group), like dialogues, consultation, polling and voting than enhance citizen engagement (offered by virtual, digital, smart and ubiquitous city classes).
- *SG3: smart business services* (Real estate market-driven group), that concern business installations' support or digital marketplaces and tourist guides (met in digital and smart city classes).
- *SG4: smart health and tele-care services* (Healthcare market-driven group) offer distant telematics support to groups of citizens (e.g., elderly people) (appear in digital and smart city classes).
- *SG5: smart security services* (Public Safety market-driven group) that enhance public safety and emergency (ubiquitous city class).
- *SG6: smart environmental services* (Utilities market-driven group) address environmental protection and mainly concern waste collection and recycling, emission control, as well as utility services (e.g., energy and water) (met in ubiquitous and eco-city approaches).
- *SG7: intelligent transportation* (Transportation market-driven group) concern traffic control and public transportation optimization (offered by digital and smart city approaches).
- *SG8: typical telecommunication services* (Real estate market-driven group) such as broadband connectivity, digital TV etc. (offered by broadband, mobile, digital, smart and ubiquitous approaches).
- *SG9: smart education services* (Education market-driven group), that concern distant learning services and online libraries (available in smart and digital city approaches).

The concept of smart service classification was that when a smart city "migrates" from one class to another, a corresponding change to the offered services is being performed and vice versa. Moreover, the only means to discover in which class a smart city belongs is to investigate literature (publications and reports) and the types of services that the city offers (either with person visits or according to the official websites). In this respect, Anthopoulos and Fitsilis (2013) concluded to the following findings (Table 2.4).

The next step was to observe when a shift from a service group to another occurred, which concerns a corresponding shift to a different smart city class (Fig. 2.4).

Except from literature findings, Anthopoulos and Fitsilis (2013) utilized data from personal visits and the official websites of the investigated cases (Table 2.3), which were processed with the technology roadmapping method and resulted to a demonstration of smart city classes evolution (Fig. 2.5).

Data from (Tables 2.3 and 2.4) show that most smart cities did not retain their initial technological type but they evolved to different forms. Moreover, this data extract path-dependent roadmaps (Li et al. 2009) of (Fig. 2.6), which demonstrate smart city updates and how each change depends on its own past. Path dependency can explain smart city evolution on the basis of smart service provision, while paths do not demonstrate co-existences of cases in more than one groups (e.g., Trikala simultaneously belonged to SG6, SG7 and SG8). Moreover, SG1, SG2, SG3 and SG8 are root nodes, while SG6 is an end-node, illustrating that this smart city type (environmental services) has not evolved to a different approach yet. Furthermore, these smart city classes meet market-driven approaches and this assignment depicts that various projects are mostly preferred (fragmented box) at an international level, while PPP (Dream box) and private (IT box) initiatives follow.

Technology roadmapping for these smart service groups shows that the smart city evolution did not pass though all classes, neither cities have evolved from all classes to all the others. On the contrary, seven (7) path-dependent roadmaps can be observed (Fig. 2.4):

1. SG1-SG3-SG7-SG6
2. SG1-SG5-SG7-SG6
3. SG1-SG3-SG5-SG7-SG6
4. SG2-SG4-SG5-SG7-SG6
5. SG8-SG6
6. SG9-SG7-SG6
7. SG9-SG6

This finding can be interpreted by the following hypotheses: (a) not all smart city technological approaches are suitable to be followed by all urban areas, but various parameters could determine to which direction a smart city must evolve. However, it is beyond the purpose of this chapter to determine these variants. (b) Not all approaches have attracted smart city technological evolution, but environmental smart service provision appears to be preferable, which sounds normal after the emphasis that international organizations give on climate change effects and urban sustainable future. Furthermore, smart cities that provide smart business, broadband and transportation services have also been popular. Finally, (Fig. 2.5) illustrates the evolution timeline of the alternative smart city classes, where five of them still exist.

**Table 2.4** Smart city classification (Anthopoulos and Fitsilis 2013)

| Case | Started | Smart service class | Market-driven class |
|---|---|---|---|
| AOL cities | 1997 | Online city guides, information from local enterprises (SG3) | BrownField, IT Box |
| Digital city of Kyoto | 1996 | GIS information about the city, city guide, municipal transportation, crowd sourcing, 3D Virtual Tour (SG3) | BrownField, IT box |
| Bristol | 1997 | Advertising spaces, connection with citizen's personal sites, public information (SG1, SG2, SG3) | GreenField, dreambox box |
| Amsterdam | 1997 | Energy management, smart building, tele-presence conference centers, grid energy solutions, sustainable public spaces, sustainable working (SG1, SG6, SG7, SG8) | GreenField, Fragmented Box |
| Copenhagen | 1989 | Local e-Government services, national e-Government services, city guide, e-Parking services, guides for entrepreneurship (SG1, SG2, SG3, SG7) | GreenField, Fragmented Box |
| Craigmillar | 1994 | Self-recycle services, local online news, job opportunities in the city Marketplace for cars and property (SG6, SG7) | BrownField, IT Box |
| Blacksburg | 2001 | GIS services, crowd sourcing, MAN, 3D Virtual city model with crowd sourcing options, broadband services, online guides and training for entrepreneurs (SG2, SG3, SG8) | BrownField, IT Box |
| Seoul | 1997 | Wired and Wireless broadband internet services, digital mobile TV (SG8) | GreenField, Dream Box |
| Beijing | 1999 | Wired and Wireless Broadband Services, smart olympic buildings (SG8) | GreenField, Fragmented Box |
| Helsinki | 1995 | Regional map service, WLAN hot spots, e-health cards (SG3, SG4, SG8) | GreenField, Dream Box |
| Geneva | 1994 | Wired and Wireless Broadband Services, Public Information and public service guides, Tourist Guides, Job Opportunities (SG1, SG3, SG8) | GreenField, Dream Box |
| Antwerp | 1995 | e-Government services (e-Counter), Online Tourist Guide, e-Booking Property Database, environmental information and guides for entrepreneurs (SG1, SG3, SG6) | GreenField, Fragmented Box |
| New York | 2004 | Wireless broadband services, e-Government portal, GIS city information (SG1, SG8) | BrownField, IT Box |

(continued)

**Table 2.4** (continued)

| Case | Started | Smart service class | Market-driven class |
|---|---|---|---|
| Stockholm (Kista) | 2002 | Residential parking permits, e-government services, elderly care treatment (SG1, SG6, SG8) | GreenField, Fragmented Box |
| Taipei | 2004 | Intelligent transportation, e-parking, 3D website for virtual tours, public e-Services, e-Future classroom (SG1, SG3, SG9) | GreenField, fragmented box |
| Dongtan | 2005 | Eco services like smart grids, energy/water/waste smart management, green buildings (SG6) | GreenField, fragmented box |
| Tianjin | 2007 | Eco services like smart grids, energy, water and waste smart management, green buildings (SG6) | GreenField, fragmented box |
| Barcelona | 2000 | e-Government services, mobile services, online city guide, guides for entrepreneurs, Intelligent transportation, open data from city council (SG1, SG3, SG7) | GreenField, fragmented box |
| Hull (U.K.) | 2000 | e-Government information and e-Services, GIS maps (SG1) | GreenField, fragmented box |
| Trikala | 2003 | Tele-care services, intelligent transportation, wireless broadband services (SG6, SG7, SG8) | BrownField, black box |
| Brisbane | 2004 | e-Parking, e-Government services, mobile services, e-Procurement services via national portal, virtual communities (SG1, SG2, SG7) | BrownField, fragmented box |
| Malta | 2007 | Smart grids (SG6) | BrownField, fragmented box |
| Dubai | 1999 | Media services, e-Education, e-Commerce, Develops business services (SG3, SG9) | BrownField, black box |
| New Songdo | 2008 | Intelligent buildings, ubiquitous computing, local information (SG6, SG8) | GreenField, dream box |
| Osaka | 2008 | Tourist guides, public information, guides for entrepreneurs (SG1, SG3) | GreenField, dream box |
| Manhattan Harbour, Kentucky | 2010 | Intelligent Buildings, Ubiquitous computing (SG6, SG8) | GreenField, Fragmented Box |

(continued)

**Table 2.4** (continued)

| Case | Started | Smart service class | Market-driven class |
|---|---|---|---|
| Masdar | 2008 | Renewable resources and smart energy management (SG6) | GreenField, dream box |
| Cape Town | 2000 | Environmental services, tourist guides, intelligent transportation (SG3, SG6, SG7) | GreenField, dream box |
| Knowledge based cities | 1998 | Broadband and telecommunications services, online city guides, public information (SG1, SG2, SG3) | BrownField, IT Box |

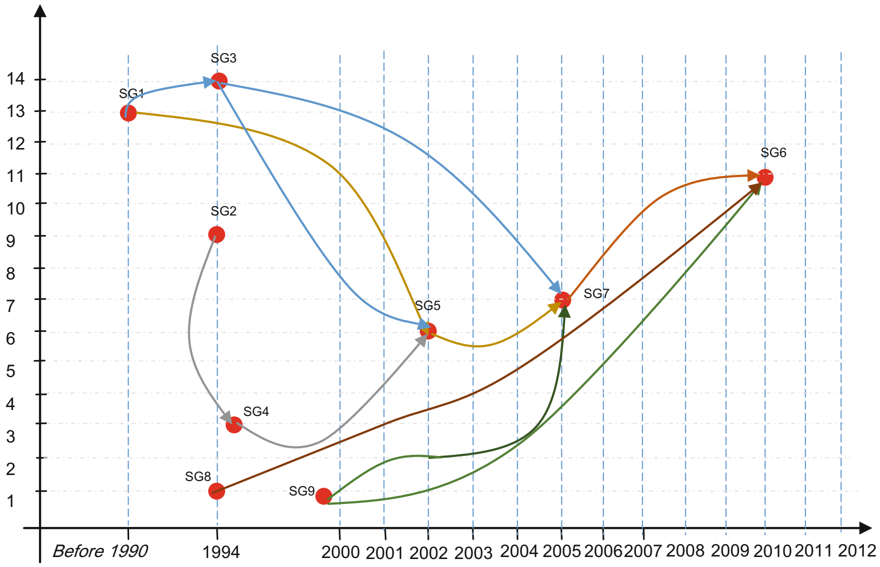


**Fig. 2.4** Smart city evolution according to (Table 2.4)

The reasons that lie behind this evolution are not clear. Probably technological evolution of corresponding ICT is the primary reason or that the smart city owners eager to offer more sophisticated smart services. Anthopoulos and Fitsilis (2013) grounded a theory that viability—the “feasibility and the operational continuity of an organization, a business, a facility or a project’s outcome in political, social, legal, environmental, economic, and financial terms”—is the primary reason. In this respect, a smart city evolves in order to sustain against radical changes, coming both from internal (e.g., service demand, political willing etc.) and external sources (e.g., city competition, climate change etc.). However, this theory remains to be validated.

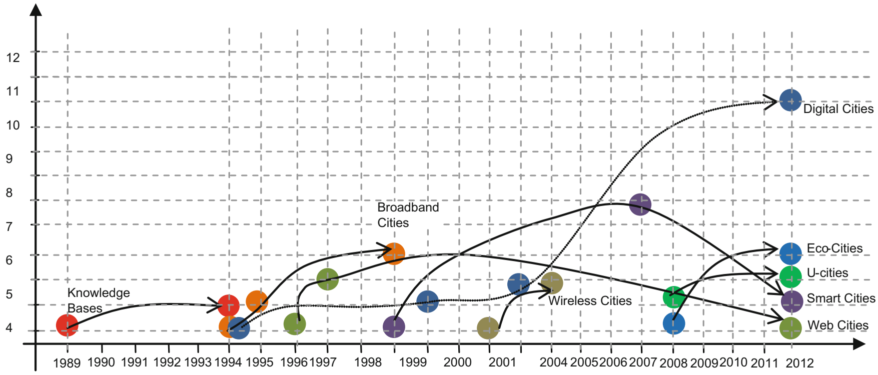


**Fig. 2.5** Smart city class evolution according to (Table 2.3)

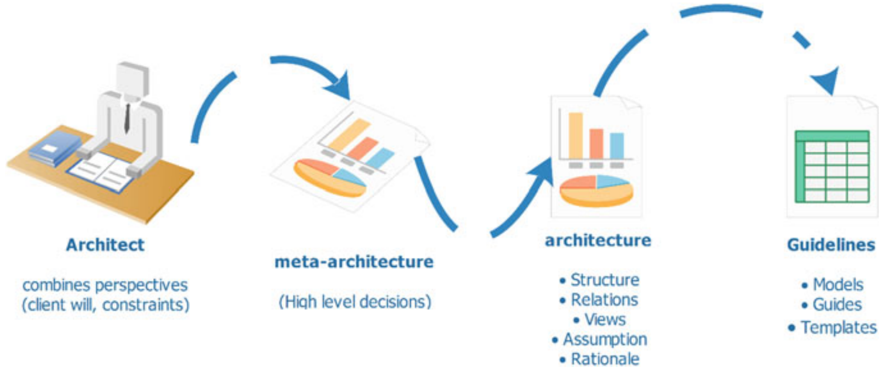


**Fig. 2.6** ICT architecture development methodology

## 2.5 Smart City Architecture

The term architecture describes several technological aspects, which range from information structure to technology delivery or ICT management (Perks and Beveridge 2003; McGovern et al. 2003). However, the most familiar use for the term concerns the formulation of physical structures such as systems or buildings. In this respect, architecture concerns *a definition of the structure, relationships, views, assumptions and rationale of a system.*

According to this definition, the architecture concerns something with a defined structure (e.g., a building is based on solid and coherent purpose and use). The building's architect has to respect several aspects, ranging from the client's will, site's requirements, legal and financial constraints, technology limitations, the building's users etc. In this sense, the architecture concerns *a pragmatic, coherent structuring of a collection of components that through these factors supports the vision of the full "user" in an elegant way.*

Following up the above definition, an ICT system has also an architecture, which offers the following features:

- It is used to define a single "system".
- It describes the functional aspects of the system.
- It concentrates on describing the structure of the system.
- It describes both the intra-system and inter-system relationships.
- It defines guidelines, policies, and principles that govern the system's design, development, and evolution over time.

Each system's component has to be defined with the same or alternative architectural practices (hardware, software, data flow, business flow, management, etc.), which can represent alternative architectural perspectives, which at high level synthesize the enterprise ICT architecture (Perks and Beveridge 2003):

- The *information architecture* deals with the structure and use of information within the organization, and the alignment of information with the organization's strategic, tactical, and operational needs.
- The *business systems architecture* structures the informational needs into a delineation of necessary business systems to meet those needs.
- The *technical architecture* defines the technical environment and infrastructure in which all information systems exist.
- The *software or application architecture* defines the structure of individual systems based on defined technology.

The definition of an ICT architecture has a lot to do with information collection and understanding of all the stakeholders' needs, together with the limitations that come from the external environment and of the laws that impact the operation of system. As such, the following process is suggested to lead the architecture development (Fig. 2.6).

Since the smart city is based on the ICT for innovation production and development, its architecture development process has to respect the above methodology. From the above architecture types, *technical architecture* is of interest to demonstrate smart city synthesis (Anthopoulos 2015a, b; ITU 2014b), since it is the element which:

- describes and defines the structure of the environment in which business systems are delivered;
- creates and maintains a set of core technology standards, with which the smart city organization can measure technology projects;
- is an organizational capability—the people within (and outside) the ICT organization who provide strategic technical advice;
- is a means of resolving organizational technical issues;
- sets system (and hence software architecture), project, and corporate technology direction;
- establishes a reasoned approach for the integration of technology and business systems;

- establishes a framework for technology procurement decisions;
- both provides input to and is driven from the ICT planning process;
- allows the organization to control technology costs;
- develops a clear understanding of an organization's critical technical issues;
- provides a governance structure to support the ongoing health of the organization's technical environment;

Following the methodology of (Fig. 2.6) the process for the smart city architecture definition consists of the following steps:

- Smart city meta-architecture definition.
- Smart city ICT architecture alternatives' definition.
- Smart city frameworks' and patterns definition.

The above process consists of the following steps (ITU 2014b):

1. *Needs' identification*: it concerns the realization of the existing city services. The ICT innovation addresses the enhancement of urban living in terms of people, quality of life (living), environment, governance, economy and mobility.
2. *Stakeholders Identification and Needs Analysis*: it determines stakeholders with their roles and responsibilities in smart city. Since stakeholders are the entities with special interest in the smart city, some of them can be considered to be *the local, regional and national governments; city service and utility providers; ICT companies; Non-Government Organizations (NGOs); international, regional and multilateral organizations (e.g., United Nations, standardization bodies* etc.*); industry associations; academia; citizens and communities;* and *urban planners*.
3. *Scope definition*: it specifies space (geographic area) and time (duration) for the architecture. The applied ICT has to respect both *hard* (e.g., networks of transport, water, waste, energy etc.) and *soft* (e.g., social and human capital; knowledge, inclusion, participation, social equity, etc.) urban infrastructure, while it has to be applicable both on *new* and *existing* cities or districts. Finally, the applied solutions have to comply with all smart city classes (from *virtual* to *eco cities*).

    1. *Architectural principles' definition*: it specifies the principles that the architecture respects. The architecture has to be applicable on *different geographic areas*; *alternative technological artefacts* that are already installed in the city (e.g., legacy systems and telecommunication networks); *city class* (small or big city, global or local city; and new or existing); and *different timeframes* within which the architecture is requested to operate (small communities evolve slower compared to global cities). In this regard, the architectural principles that the smart city architecture has to respect concern:

        a. *Layered structure*: it is proved to be the best manageable option and it is followed in most of the examined cases (Anthopoulos and Fitsilis 2014);
        b. *Interoperability* between alternative city solutions;

c. *Scalability*: able to scale-up and down;
d. *Flexibility*: able to adopt cutting edge technologies, while physical or virtual resources have to be rapidly and elastically adjusted to provide various types of smart services;
e. *Fault tolerant*: respect many quality attributes regarding system performance;
f. *Availability, manageability and resilience*: ensure service availability and recovery after disasters;
g. *Standards-based*: it should ensure contestability, replace ability, and longevity
h. *Technology and/or vendor independence*: the architecture must be open and compatible with alternative solutions.

4. *Functional Requirements' definition*: it identifies the subsystems that deliver the smart city services. The minimum set of functions that the architecture must ensure concern *cybersecurity, data protection and cyber resilience; privacy; integrated management; hard infrastructure and environmental management; service delivery; and information flow.*
5. *Subsystem and Interface definition*: it demonstrates how the identified subsystems are connected and specifies the interfacing requirements. It is the outcome of the application of alternative architecture views (functional; implementation; physical; business process domain and software engineering).
6. *Dataflow Analysis*: it analyzes dataflow between smart city subsystems.
7. *Information Security and Privacy Requirements' definition*: it addresses all necessary information security requirements according to previously identified needs, functional requirements, interfaces and dataflow specifications for each subsystem.
8. *Systems Analysis and Final Design*: it analyzes potential merging of subsystems, as well as exclusion or inclusion of subsystem module.

The above process steps initially result to the definition of the smart city meta-architecture (Fig. 2.7), which incorporates the following components:

- **Soft infrastructure**: people, knowledge, communities, business processes etc.;
- **Hard infrastructure**: buildings, city facilities (e.g., roads, bridges, telecommunications networks etc.) and utilities (e.g., water, energy, waste, heat etc.);
- **ICT-based innovation**: both hardware and software solutions, which can be embedded in the above hard and soft infrastructure or deliver corresponding smart services;
- **Non-ICT based innovation**: innovation—beyond the ICT—that addresses smart city dimensions (e.g., creativity, open spaces, recycling and waste management, smart materials, organizational innovation in government, etc.)
- **Physical environment**: concerns the natural landscape of the city (e.g., ground, forests, rivers, mountains, etc.).

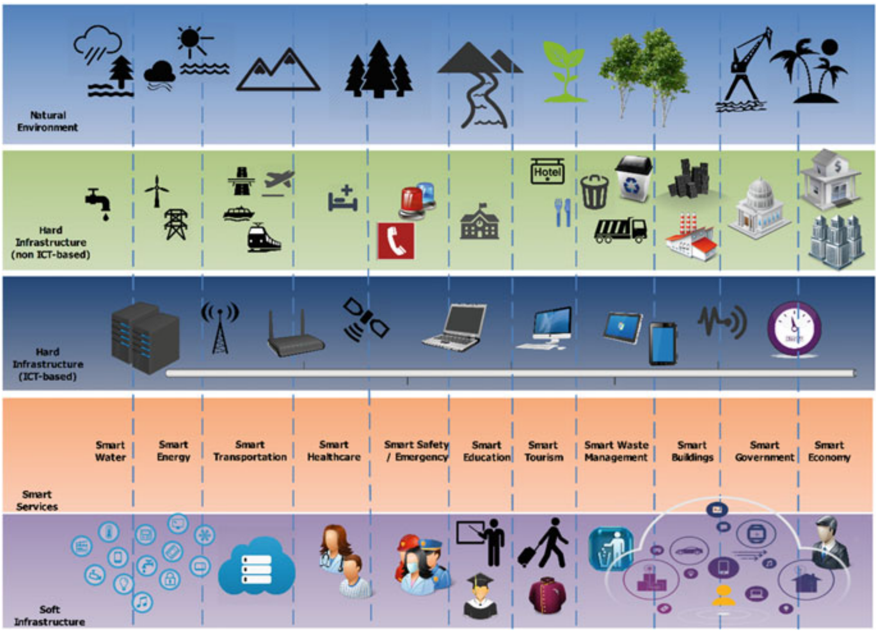


**Fig. 2.7** Smart city meta-architecture

In this regard, the resulted multi-tier meta-architecture consists of the following layers from top to bottom (Fig. 2.6):

***Layer 1—Natural Environment***: respecting all the environmental features where the city is located.
***Layer 2—Hard Infrastructure (Non ICT-based)***: it contains all the urban facilities (e.g., buildings, roads, bridges, energy-water-waste-heat utilities, etc.).
***Layer 3—Hard Infrastructure (ICT-based)***: it concerns all hardware, with which smart services are being produced and delivered to the end-users (e.g., datacenters, telecommunication networks, IoT, sensors, etc.)
***Layer 4—Smart Services***: the smart services that are being offered via both the hard and soft infrastructure (e.g., smart safety, intelligent transportation, smart government, smart water management, etc.):

- Smart Transportation: e.g., parking management, intelligent transportation, traffic management, etc.
- Smart government: typical administrative procedures, service co-design platforms etc.
- Smart economy: typical intra-organization and inter-organization services, which are supported by the ICT (e.g., Enterprise Resource Planning (ERP) and

Customer Relationship Management (CRM) functions, online procurement systems, e-banking systems, etc.).

- Smart Safety and Emergency: accident management (e.g., traffic accidents), crime prevention, public space monitoring, climate effects' changes, alerting and emergencies (e.g., in cases of kidnapping and natural disasters, etc.).
- Smart health: tele-medicine, tele-care, health record management, etc.
- Smart Tourism: city guides, location based services, marketplaces, content sharing, etc.
- Smart Education: distance learning, digital content, digital libraries, ICT-based learning, ICT-literacy, etc.
- Smart Buildings: building performance optimization, remote monitoring and control, etc.
- Smart Waste management: monitoring, city waste management, emission control, recycling with the use of ICT, etc.
- Smart Energy: artificial lighting, smart grids, energy efficiency's management, etc.
- Smart water: quality measurement, water management, remote billing, etc.

**Layer 5—Soft Infrastructure**: individuals and groups of people living in the city, business process, software applications and data, with which the smart services are executed and being realized.

From the management view (service provider), all the offered smart services are being generated and transferred via separate subsystems. Each subsystem requires both infrastructure and software to operate, its uses and produced data, while it transacts with end-users (demand and supply side) and with other subsystems. In this respect, various types of transactions are being performed within the smart city architecture and between end-users and architecture subsystems. Indicatively, these transactions concern (ITU 2014b):

- Information and service requests (demand side end-users);
- Information and service delivery (supply side end-users and sub-systems);
- Information and service requests (demand side subsystems);
- Information and service delivery (supply side subsystems);
- Information storage (demand side subsystems);
- Information retrieval (supply side subsystems).

Individual interfaces allow transactions flows from/to a subsystem, while several user interfaces enable transactions with the end-users (demand and supply side). In order for the smart city architecture to be realized, a representative view is being presented, which concerns the communications view (ITU 2014b). This view is closer to the infrastructure developer and it examines the networking elements of the architecture in the nexus of geographic constraints, bandwidth requirements etc. Various alternatives can be followed to establish communications between smart city ICT architecture subsystems:

- Wired networks (fiber-optic, coal-based networks within the city, etc.) that structure wide, regional or local area networks;
- Wireless networks (WiFi, WiMax, GSM, 4G mobile networks, etc.);
- Peer-to-Peer connections between ICT architecture sub-systems;
- Distributed Object Management (DOM);

The communications view of the architecture is a multi-tier too and consists of the following layers (Fig. 2.7) (ITU 2014b):

- *Sensing layer*: consists of terminal node and capillary network. Terminals (sensor, transducer, actuator, camera, RFID reader, barcode symbols, GPS tracker, etc.) sense the physical world. They provide the superior "environment-detecting" ability and intelligence for monitoring and controlling the physical infrastructure within the city. The capillary network (including SCADA, sensor network, HART, WPAN, video surveillance, RFID, GPS related network, etc.) connects various terminals to network layer, providing ubiquitous and omnipotent information and data.
- *Network layer*: indicates facilities that are being provided by telecommunication operators, as well as other metropolitan networks provided by city stakeholders and/or enterprise private communication networks. It is the "infobahn", the network layer data and support layer: The data and support layer makes the city "smarter", its main purpose is to ensure support capabilities of various city-level applications and services. Data and support layer contains data center from industries, departments, enterprises, as well as the municipal dynamic data center and data warehouse, among others, established for the realization of data process and application support (Fig. 2.8).
- *Application layer*: The application layer includes various applications that enable the smart city management and deliver smart services.
- *Operation, Administration, Maintenance and Provisioning, and Security (OAM & P & security) framework*: ensures operation, administration, maintenance and provisioning, and security function for the ICT systems.

Except from the multi-tier architecture approach, a ***modular*** structure for a smart city can be also performed (ITU 2014b). However, modular definition is a complex process and it has to consider both the city type and the architecture view. Smart city soft infrastructure (people, data and applications) is flexible, extensible and easy to interconnect. On the contrary, hard infrastructure and physical environmental features place many restrictions in modular definition. Except from the previously presented conceptual models, various attempts to a modular smart city architecture (Cruickshank 2011; Kuk and Janssen 2011; Kakarontzas et al. 2014; Al-Hader et al. 2009) suggest a structure that consists of the following components (Fig. 2.9):

(1) *Smart City Networking Infrastructure and Communications Protocol*: addresses the necessary network infrastructure (telecommunications networks and IoT) to deploy smart services and enhance living inside the city.

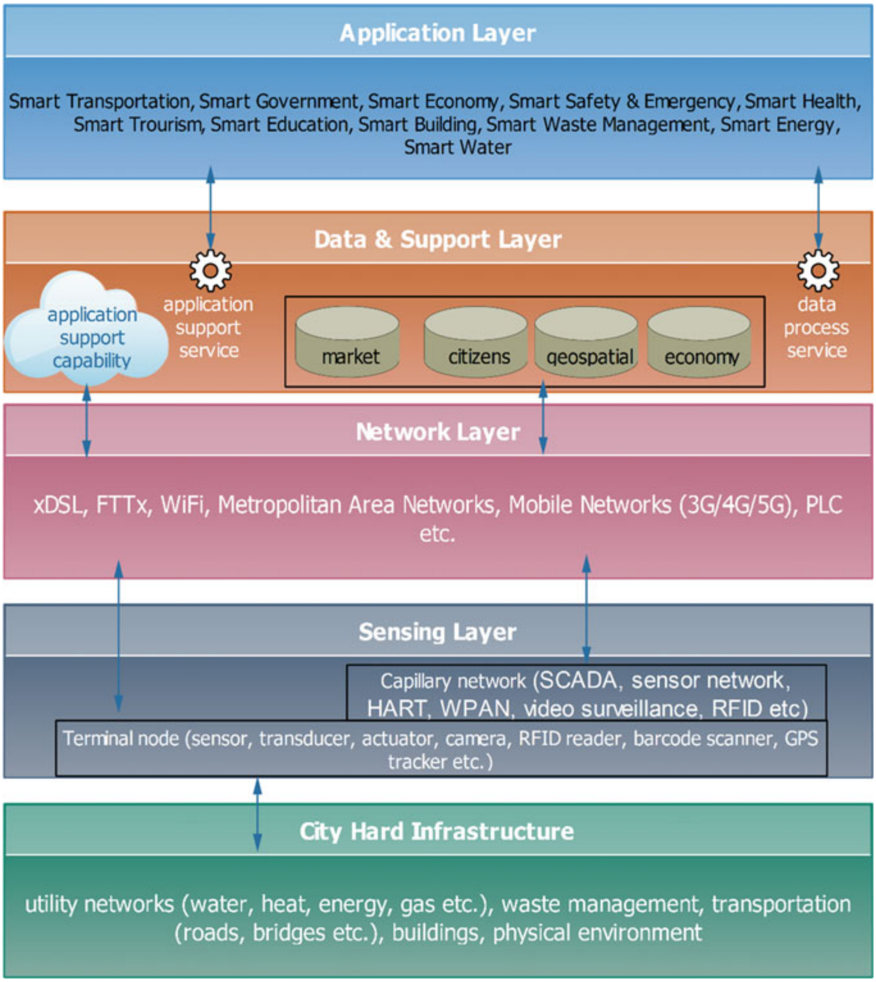


**Fig. 2.8** Multi-tier architecture from communications view

(2) *Applications*: concerns all the smart applications, which are available inside the smart city ecosystem. These applications could be classified in the 6 smart city components (people, mobility, government, economy, environment and living).

(3) *Business*: it refers all business groups, which are available inside the smart city ecosystem and use smart applications. This particular module deals with the following information management issues:

- User information for consumer behavior's recognition.
- Business intelligence for statistical and feasibility studies.


Fig. 2.9 Smart city modular architecture

- Industry information for market demand monitoring.
- Business information for commercial and financial analysis.
- Revenue Information for market cash flow and daily business activities' realization.
- Circulation Information for emerged business cases' estimation.

(4) *Management*: contains all rules and procedures for managing a smart city. The primary elements of this module concern:

- Information management: information collection and dissemination across the smart city.
- Process management: ICT management from a business transaction perspective.
- People management: human and workflow management in terms of a sequence of operations within the city, like a single organization and visualization.
- Land/spatial management: urban and rural planning processes, as a means to secure sustainable land use.
- Resource management: resource utilization (e.g., machines, vehicles etc.).

(5) *Data*: data is crucial in smart cities and can be either used or produced, while they can be stored centrally or in a distributed manner (locally). It is analyzed in the following components:

- People data: individual information, which is produced by inhabitants and are mostly preserved with privacy issues.
- Process data: It is produced during smart service execution and routine transactions between machines and/or people.
- Documents: These are mainly used or produced by government applications or within the business sectors. Documents can be also the basis of smart service controls (e.g., quality assurance, disaster recovery plans, etc.) and can be organized in digital repositories.
- Geospatial: used and stored by Geographical Information Systems (GIS).
- Business data: created in the business module and by smart economy applications.

Finally, with regard to the architecture guidelines, these have to satisfy the following aspects:

- Security and Privacy requirements.
- Quality requirements: the minimum set of quality requirements for each architecture's subsystem and for the overall architecture performance. A set of principles for the smart city architecture was presented above, some of which are totally quality-based (e.g., manageability, fault-tolerance, scalability, etc.)
- Guides for each subsystem: most of the above modules can be standardized.

Indicative details regarding these requirements and guides are given by corresponding standards (e.g., ITU 2014b).

## 2.6 Conclusions

This chapter attempted to explain the smart city context. It explained the corresponding terms from works coming from both literature and industrial standards and defined the smart city with the corresponding outcomes. In brief, this "umbrella" definition concerns *a combination of innovation and ICT within the urban space, as a means to deal with specific challenges*. Several scholars have conceptualized the smart city with different perspectives, which complicate the smart city nexus and in this regard, existing works were compared and combined to return a unified conceptualization smart city framework that collects all existing theory and experience.

Moreover, this chapter presented how the smart city evolved in time. This evolution was neither easy nor clear. Several smart city types have been grounded, they have attracted many city cases since their initial appearance in literature (1997) and either evolved or declined. These smart city types were differentiated according to the technology that was used as the basis for city ICT innovation and evidence show that *eco city* is the most preferred technological type. Finally, an emphasis on smart city ecosystem returns useful smart city architectures, which differ according to the preferred view. In this respect, the architecture framework is useful to support smart city owners and leaders in developing the appropriate solution for their city, while smart city vendors can deploy their products within the corresponding architecture, specifications and guides.

Nevertheless, smart city is an emerging domain and new models for their evolution appear like *Sharing Cities* (Ishida 2017), where sharing economic models (i.e. Uber and Airbnb) are utilized and local resources are being commercialized, while local capital is socialized in order for the cities to sustain in economic and environmental terms. In this regard, all the above analysis generates a collected "snapshot" of findings coming from the timeframe of 20 years of smart city evolution (1994–2016) and normally, new smart city types—accompanied by novel definitions and technologies—are expected to appear in the future.

| | |
|---|---|
| Revision Question 1: | which were the initial smart city types? |
| Revision Question 2: | what does technological embeddedness mean? |
| Revision Question 3: | what is the purpose of a smart city conceptualization model? |
| Revision Question 4: | which groups of conceptualization models exist? |
| Revision Question 5: | which are the 8 smart city components? Explain them. |
| Revision Question 6: | what is the definition of an ecosystem? |
| Revision Question 7: | what are the elements that structure an ecosystem? |
| Revision Question 8: | what is the self-congratulatory tendency? |
| Revision Question 9: | what is the purpose of the smart city coalitions/groups? Can you name 2 of them together with their scope? |
| Revision Question 10: | which are the city classification methods and their classes? |
| Revision Question 11: | how have smart cities evolved? Are there any change patterns? What is the source of this evolution? |
| Revision Question 12: | describe the smart city architecture development process. |
| Revision Question 13: | which are the smart city stakeholders? |
| Revision Question 14: | choose and describe the structure of a smart city architecture. |
| Revision Question 15: | what are the aspects that the architecture guides must satisfy? |

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