



Smart Cities and Sustainability: A Set of Vertical Solutions for Managing Resources

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Abstract. The Smart City vision can be viewed as a “system of systems”, where all systems within it are interconnected, in constant communication with each other in real time, exchanging information, and making smart decisions all in a sustainable and highly efficient model. Two decades ago, the Smart City concept was born to address emerging city sustainability issues and was mainly focused on energy efficiency and greenhouse gas emissions reduction. More recently the term was attached to the role of ICT infrastructure. This paper aims to clarify interrelations between the Smart City concept and fostering the sustainable development of cities. The paper is based on an analytical study of the main characteristics and systems of a Smart City, emphasizing the significant role of Future Internet in the development of Smart Cities. The first section is a short introduction to challenges and drivers for a Smart City. Sections two and three discuss the technological context of Future Internet and the expected impact of Internet-of-Things, sensors, tags, and cloud computing on Smart Cities. The next two sections analyze the main Smart City Systems and approaches for managing them. Moreover, sections six and seven analyze two of the top performing Smart Cities in Europe and also address the UAE 2021 Vision in order to assert the environmental impacts that occur as a result of transforming into a Smart City. This paper concludes with a common framework for transforming cities into smart ones, which depends on the nature, circumstances, and resources of each city.

Keywords. *Smart Systems, Information and Communication Technology (ICT), Data Centers, Future Internet, Internet of Things, Cloud Computing, New Urban User Experiences, Amsterdam, Barcelona*

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1. Introduction

If present trends continue, there will be more than 9 billion humans in the world in 2050, and about 70 % of them will live in urban areas. Due to the rapid urbanization, there are overwhelming challenges for cities' authorities to meet, like complex service delivery challenges and increased demand on ageing city infrastructure (Figure 1). Moreover, we have experienced multiple revolutions in technologies in the fields of ICT, renewable energies, electric vehicles, etc. (Nicholson, 2010). There will be an urgent need for smarter, more sustainable cities to make life bearable for so many people. The Smart City term is used in a holistic way to describe various aspects ranging from Smart City as an IT-district

to a smart city regarding education or smartness of its inhabitants.

The Smart City notion has also been approached as part of the Digital City broader term, where a generic multi-tier common architecture for digital cities was introduced and assigned smart city to the “Service Layer”. The generic multi-tier architecture contains the following layers: (Anthopoulos and Vakali, 2012) (Figure 2)

- *User layer:* Concerns both local stakeholders who supervise the city and offer e-services and end-users who consume services
- *Service layer:* Incorporates all e-services offered

- *Infrastructure layer*: Contains network information systems and other facilities that contribute to e-Service deployment.
- *Data layer*: Presents all information that is required, produced and collected in a smart city.

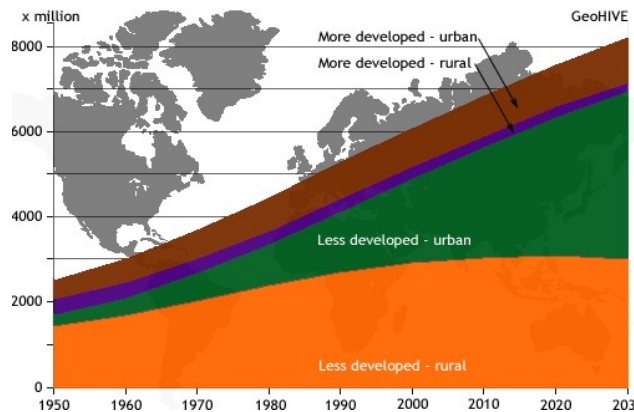


Figure 1: The urban and rural population of the world 1950-2030. More developed regions comprise all regions of Europe, Northern America, Australia/ New Zealand and Japan. Less developed regions comprise Africa, Asia, Latin America, etc. Source: Population Division, United Nations

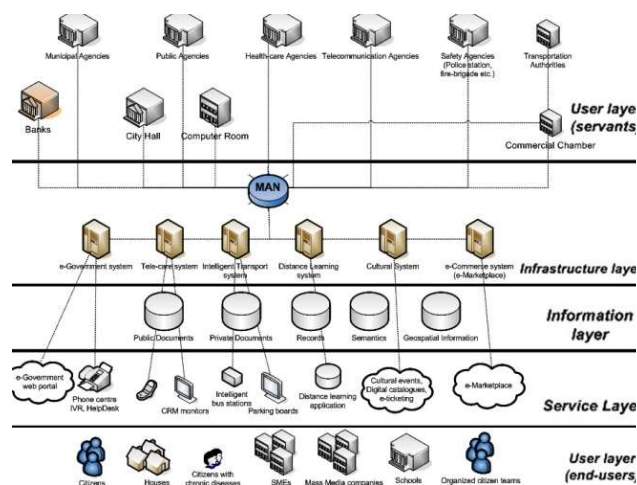


Figure 2: Generic multi-tier common architecture for digital cities. Source: Anthopoulos and Vakali, 2012

The Smart city concept recognizes the growing importance of ICT infrastructure as drivers of economic competitiveness, environmental

sustainability, and general livability. The right ICT infrastructure will affect the way each city is created and evolves by enabling Smart Cities to include vastly enhanced sustainable areas and improve and support urban operations and services, thus creating new urban user experiences. The ICT infrastructure includes: (European Commission DG INFSO, 2008)

- *Data Centers* – This category contains small to large servers and their respective infrastructure including air conditioning systems, lighting systems, switches, etc.
- *Core Telecom Networks* – This category contains copper or optical fiber telecommunication lines with respective terminals, router, and switches.
- *Cellular Phone Networks* – This category contains 2nd and 3rd generation mobile phone telecommunication with base transceiver stations, main switch controls, and other network components.
- *TV/Radio Broadcast Equipment* – This includes radio relays, directional radio antennas, etc.
- *Wireless Local Area Networks* – This category contains WLAN equipment such as base stations and repeaters.

To fully conceive the Smart City paradigm and the complex interplay between the systems of a Smart City (which are composed of infrastructures, assets, behaviors, etc.), this paper covers three main tasks and a concluding section (task 4):

- *Task 1* – Starting with conceptualizing Future Internet technologies and demonstrating how they consider the essential building blocks for the development and management of Smart Cities.
- *Task 2* – In this task, we focus on analyzing the vision of a Smart City as a “system of systems”. This is done through investigating the main systems and characteristics and factors of a Smart City.
- *Task 3* – This task focuses on proving the environmental impacts caused by the application of ICT-based technologies in various sectors of the city. This is done through examining some of the main initiatives and projects taken by two of the

top performing European cities (Amsterdam and Barcelona) in their transformation into Smart Cities as a response to the Europe 2020 Strategy as well as demonstrating briefly the Dubai Smart City Strategy in line with the UAE Vision 2021 as a significant example from the Middle East.

- *Task 4* – Based on the previous analysis, we conclude with a common framework for transforming cities into smart ones.

2. Future Internet (FI)

The major ICT requirements for a smart city will be FI technologies because they are at the society and economy's core. FI can transform a Smart City into an open innovation platform, supporting vertical domain of business applications built upon horizontal enabling technologies.

Basic FI pillars are: Internet of Things, Internet of Services, and Internet of People (Hernández-Muñoz et al, 2011). Internet of Everything (IoE) Brings together people, processes, data, and things as the following (Evans, 2012): (Figure 3)

- *Data* – With an Internet of Things (IoT), devices typically gather data and stream it over the Internet to a central source, where it is analyzed and processed.
- *Things* – This group comprises physical items like sensors, devices, and enterprise assets that are connected to the Internet and each other. In IoE, these things will sense more data, become context-aware, and provide more experiential information to help people and machines make relevant and valuable decisions.
- *Processes* – Processes play an important role in how each of these entities (people, data, things) work with the others to deliver value in the connected world of IoE.

2.1 The Internet of Things (IoT)

The Internet of Things is the most important component of the current technology shift in Smart Cities, combining Ubiquitous Sensor Networks (USN) and Radio Frequency Identification (RFID) for robust and cost-effective identification of many objects in terms of functionality, technology and application fields. (Komninos, 2013)

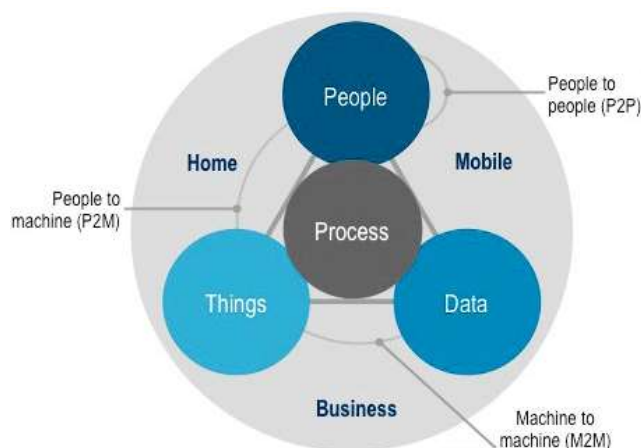


Figure 3: Internet of Everything Framework.
Source: Cisco, 2013

2.1.1 Ubiquitous Sensor Networks (USN)

Sensor networks in cities can gather enormous amounts of information from connected smart objects and grids over utility networks. Real-time response to this data and prediction of behavior patterns become possible with high capacity processing and computing power (Komninos, 2013). Basic functionalities of USN will support (Hernández et al, 2011): (Figure 4)

- *Sensor Discovery* – This functionality will provide services and applications information about all the registered sensors in the city.
- *Observation Storage*– This functionality will provide a repository where sensors' data are stored to allow later retrieval (energy monitoring, video surveillance, etc.)
- *Publish-Subscribe-Notify* – The platform will allow services to subscribe not just to sensors' observations but also to complex conditions involving also other sensors and previous observations and measurements.
- *Homogenous Remote Execution capabilities* – This functionality allows executing tasks in sensor/actuator nodes (call actuator commands).

The main principles covered by USN platforms are: (Hernández et al, 2011)

- *Unified information modeling* – The information should be provided to the Smart City

services using a unified information model, regardless of the particular information model used by the sensors deployed through the city.

- *Unified communication protocol* – Given the extension of an urban area, several standards can co-exist to communicate (ZigBee, 6Low-Pan, xDSL, GPRS, etc.).
- *Horizontally layered approach* – The platform should be built following a layered approach so services and networks are decoupled in order to evolve independently.

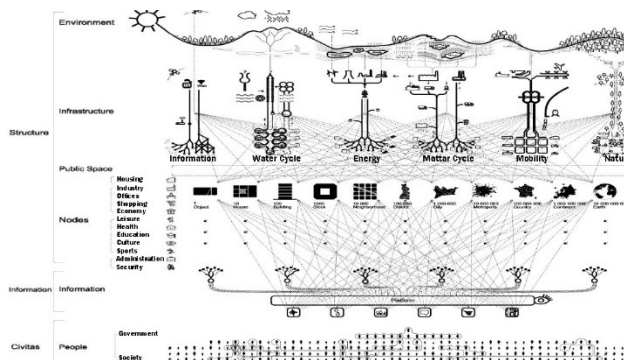


Figure 4: Wireless sensors are deployed throughout the city to automatically control the different sectors. Source: City Protocol Society, 2012

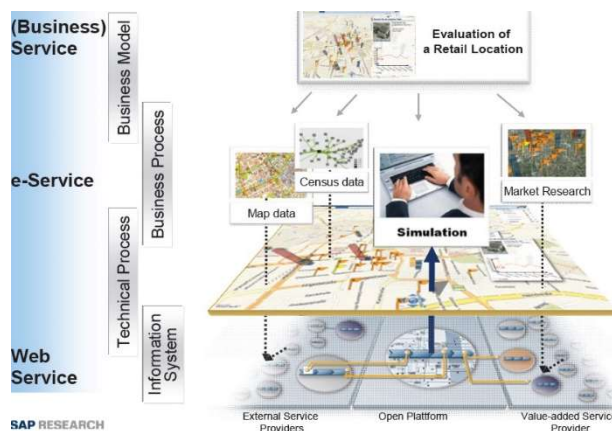


Figure 5: Internet of Services' vision. Source: SAP, 2007

2.2 The Internet of Services (IoS)

It is a vision of FI where everything that is needed to use software applications is available as a service on the Internet, such as the software itself, the tools to develop the software, and the platform (servers, storage and communication) to run it. (Komninos, 2013) (Figure 5)

2.2.1 Cloud Computing

Many cities can take advantage of cloud computing, which reduces the number of hardware components and thus the energy needed for IT systems. Here are some of the characteristics of cloud computing technology:

- It offers complementary IoT and M2M. (Komninos, 2013)
- It is based on several technological advances related to high-speed networks, virtualization, and standardization of platforms and applications. (Komninos, 2013)
- It provides computer services through the Internet. People can access apps, software development tools, and store files remotely via the Internet. (Komninos, 2013)
- The cloud is Google's Gmail, Google Docs, and Dropbox. (Komninos, 2013)
- Cloud computing has three service models (SaaS, PaaS, and IaaS).
- Government G-clouds are promising models for (larger) cities by creating urban clouds that reduce IT costs. These clouds are built to meet the needs of specific industries such as healthcare, media, and government, etc.

2.3 The Internet of People (IoP)

In IoE, people will be able to connect to the Internet in innumerable ways. Today, most people connect to the Internet through their use of devices (such as PCs, tablets, TVs, and smartphones) and social networks (Facebook, Twitter, LinkedIn, and Pinterest). (Evans, 2012)

3. Open Innovation Platform

The Smart City vision implies new models of governance and new forms of relationship between governments, businesses, and people. This requires the active participation of citizens in defining local public policy and in the process

of innovation, from the development stage to the testing of products, services, and solutions in the real world. It is the so-called paradigm of open innovation (Harrison and Donnelly, 2011). Open innovation mechanisms are relevant to Future Internet Services in Smart Cities. There are three mechanisms for open innovation: (González and Rossi, 2012)

- *Urban Labs* – A city-based Living Lab empowers users to drive research and innovation for ICT based services, addressing major socio-economic issues that will increase returns on investment in ICT research and also bridge the gap between R&D and the market.
- *Ideas Crowdsourcing* – Cities can adapt to the strategy of Ideas Crowdsourcing to enlist the help and knowledge of their citizens. Some applications have been developed such as SeeClickFix, which allows anyone to report and track non-emergency issues regarding community/infrastructure via the Internet.
- *The Use of Pubic Data* – In this mechanism, several national governments have created websites to distribute a portion of the data they collect to create open government data.

4. Smart City Infrastructure Development and Monitoring

One of the most important elements of the ICT Infrastructure for managing Smart City Systems and Assets is the Data Centre. The main purpose of a Data Centre is running the applications that handle the core business and operational data of the organization. Such common applications are Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems. An ERP system is the base of creating the smart concept either in the city or infrastructure level. The idea behind it is replacing the existing legacy systems and available interfaces into a single, functionally rich system application product to standardize all possible business models and all operational processes in one platform (Smart GIS). The concentration will be on the available utility networks to develop comprehensive, standardized geospatial data models. (Al-Hader and Rodzi, 2009) (Figure 6)

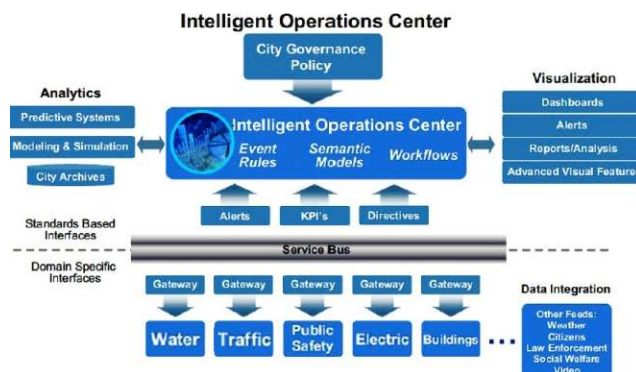


Figure 6: Smart City is perceived as a “system of systems” linking individual systems into a joint system of systems allowing them to operate together in tandem, which will bring intelligence to the individual management of City Systems. Source: Department of Science & Technology, 2013

As shown in Figure 8, Anglian Water company in UK developed an Operational Management Centre, which brings information together into a unified view and assists in rapid response to customer calls from SAP and telemetry alerts by viewing geospatially—identify clustering of problems (overlay SCADA alerts on GIS maps). It is available to Anglian Water users anywhere via web. (Al-Hader and Rodzi, 2009) (Figure 7)

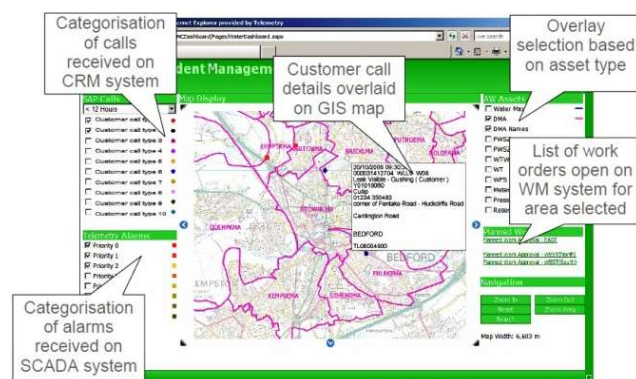


Figure 7: A project integrating GIS, SCADA, and Customer Relationship Management (CRM) information into a unified dashboard. Source: Metasphere Ltd, 2006

Table 1

Developing a transparent and hierarchical structure for a Smart City's characteristics and factors, where each level is described by the results of the level below

Smart Economy	Smart People	Smart Governance
- Penetration of ICT use in businesses - Financial promotion - Retaining and attracting talent and promoting creativity - Development of business spaces - Internationalization of the city	- Education and Training - E-Learning - Human Capital - R& D&I	- Strategic plans to promote e-Government and ICT - Website availability - On-line public services - Electronic signature - Transparent governance - E-Democracy - Promoting ICT and Innovation
Smart Mobility	Smart Living	Smart Environment
- Communication Services - Intelligent Transportation System	- Public Safety and Security - E-Health	- Smart Power Grid - Water Smart Grid - Smart Waste Management

5. Smart City Systems

The Internet is changing the traditional urban planning model and compelling planners to not only consider the physical planning of a city but also to consider the use of ICT to make the economy, environment, mobility, etc. more efficient and effective (Escher Group, 2014).

In this context, the Smart City is analyzed in an intelligent dimension, which concerns all of the six characteristics of a Smart City (Economy, People, Governance, Mobility, Environment, and Living). Each characteristic is therefore defined by a number of factors. Furthermore, each factor is described by a number of indicators.

Table 1 illustrates the six characteristics and their assigned factors. (Table 1)

5.1 Smart Economy

Smart Economy refers to cities with "smart" industries, especially in the areas of ICT as well as other industries that involve ICT in their production processes, with a focus on emerging clean technologies, sustainable business practices, and energy efficiency techniques being employed by companies in a wide range of industry sectors. This includes water technologies, fuel cells, industrial automation and control, and other business models designed to improve the efficiency of resource management within the industry verticals. Smart Economy attributes

include rewarding jobs, being a magnet for foreign direct investment and top international talent, a pool of highly educated workers, modern and responsive public service, empowered citizens, intelligent infrastructure, light and adaptive regulation, widespread adoption of modern technology, and equitable society. (Government of Ireland, 2008) (Figure 8)

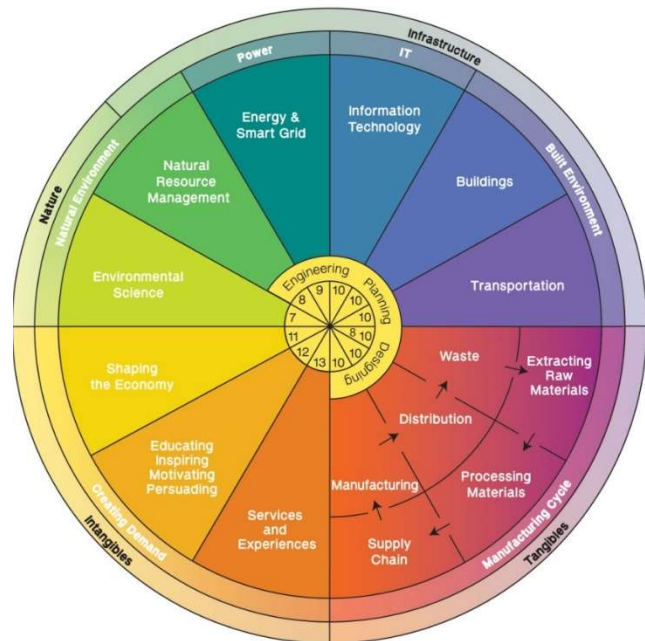


Figure 8: Industries and sectors within green economy. Source: Transition Dynamics Enterprises

5.2 Smart People

The rehabilitation of people to deal with the smart infrastructure/systems is the essence of success for smart cities. Smart People are defined by the following factors: (Azkuna, 2012)

- *Education and Training* – This factor is measured by the population's percentage with university qualifications, a strong presence of university, a wide range of educational specialization areas offered by the city, and educational offer's adaptation to the current labor market demand.
- *E-learning* – This factor comprises plans for digital developments in classrooms.
- *Human Capital* – This factor is indicated by the collaboration between companies and knowledge centers.
- *Encouraging Research, Development, and Innovation (R&D&I)*

5.3 Smart Governance

Smart Governance includes political and active participation, citizen services, and the use of new communication channels such as e-Government or "e-democracy". Smart governance is characterized by local public spending on ICT, website availability, strategic plans to improve public governance, and the provision of public services through promoting e-Government and ICT, online public services, electronic signature, transparent governance, and improving the consultation and decision-making processes through e-democracy. (Azkuna, 2012) (Figure 9)



Figure 9: Indiana E-government portals act as intermediaries between the citizens and the public administration units. Source: <http://www.in.gov/>

5.4 Smart Mobility

Smart Mobility has to do with providing the public with access to new technologies in everyday urban life. The infrastructure must provide the ability for all users to share and process any information instantly from anywhere. Smart Mobility is characterized by communication services and intelligent transportation systems. Smart Mobility is characterized by communication services and an intelligent transportation system. (Azkuna, 2012)

5.4.1 Communication Services

- *Connectivity and ICT infrastructure* – This factor is measured by the penetration of ICT use in homes, Internet usage, Broadband coverage, Broadband usage, mobile phone usage, and mobile Internet usage penetration. (Azkuna, 2012)
- *Public Internet Access* – This factor includes Wi-Fi hotspots in cities, public Internet access centers, and promotion deals with Internet service providers. (Azkuna, 2012)

5.4.2 Intelligent Transportation System

Transportation future lies not only in building new roads or repairing aging infrastructure but also in the implementation of technology, specifically a network of sensors, microchips, and communication devices. Intelligent transportation system applications include: (Ezell, 2010)

- *Advanced Transportation Management Systems* – Centralized traffic management centers rely on ICT to connect sensors and roadside equipment, vehicle probes, cameras, message signs, and other devices together to create an integrated view of traffic flow and to detect accidents, dangerous weather events, or other roadway hazards. (Figure 10)
- *Intelligent Transportation System-Enabled Transportation Pricing Systems* – Electronic toll collection, through which drivers can pay tolls automatically via a dedicated, short-range, communication enabled on-board device or tag placed on the windshield.
- *Advanced Public Transportation Systems* – Automatic vehicle location and electronic fare payment systems for public transportation.
- *Vehicle-to-Infrastructure Integration and Vehicle-to-Vehicle Integration.*

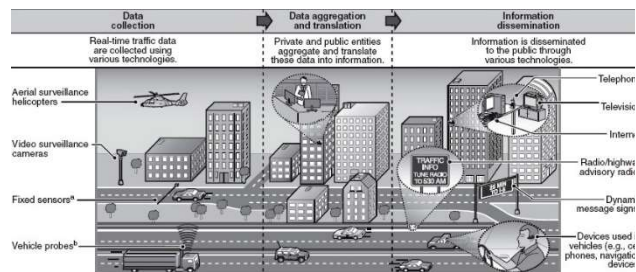


Figure 10: There are three key facets covered by The Centerized Traffic Management Centers to the provision of real-time Traffic Information Systems. Each step entails a distinct set of technology devices, platforms, and actors.

Source: ITIF, 2010

5.5 Smart Living

Smart Living integrates a lot of aspects that substantially improve the quality of life of citizens, such as culture, health, safety, housing, tourism, and more. Smart living comprises public safety and security and e-Health. (Azkuna, 2012)

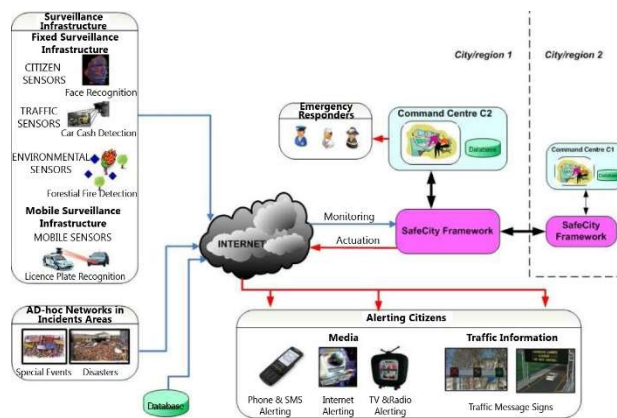


Figure 11: The SafeCity Monitoring and Actuation Framework. Source: "SafeCity: Future Internet PPP"

5.5.1 Public Safety and Security

Public safety initiatives have to serve to optimize the capacity and response time of emergency services; secure and control mass events; secure

public administration transactions and work-flow; and provide surveillance of public places. The SafeCity project demonstrates the significant role of Future Internet technologies under four main public safety areas: "situational awareness", "ad-hoc networks", "alerting citizens", and "command and control capabilities" by analyzing public safety infrastructures of several European cities. (González and Rossi, 2012) (Figure 11)

5.5.2 E-Health

The application of new technologies in ways that affect health care, from diagnosis to monitoring patients, including the management of the health organizations, is what defines e-Health. Here are some of e-Health initiatives: telemedicine, electronic health record, Mhealth, online medical services, and remote patient monitoring. (Azkuna, 2012)

5.6 Smart Environment

Smart Environment concerns the management of the main utilities through Smart Grids. The Smart Grid System will form the backbone of the Smart City because it integrates not only the energy cycle but also allows for the flexibility of the water system, waste management, and the transportation system. (Open Systems International, 2012)

5.6.1 Smart Power Grid

The existing grid infrastructure is overburdened and lacks the ability to accommodate the demands of today's digital economy for reliable, high quality electric power; and revolutionary technologies, such as renewable energy, deregulation of energy market, customers' demands (reduced outages, energy production), hybrid and electric vehicles, and sensors (Bowen, 2010). The Smart Grid concept has emerged as a way to maintain the power grid stability while enabling effective utilization of power. The Smart Grid characteristics are self-healing and adaptive, interaction with consumers, wide variety of generation options, increased grid visibility, and optimized asset and resource management. (Open Systems International, 2012) (Figure 12)

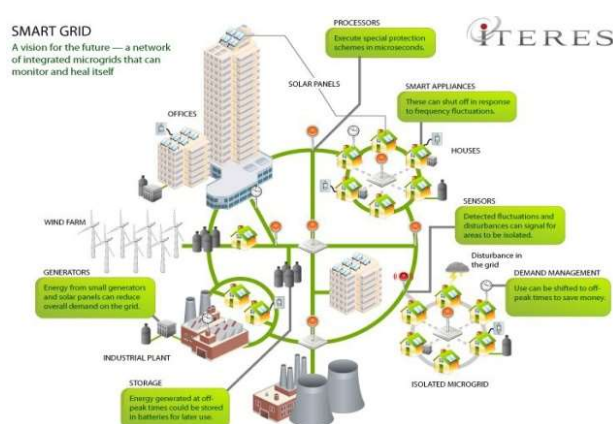


Figure 12: The Smart Grid is a network of integrated microgrids that can monitor and heal itself. Source: ITERES

5.6.2 Water Smart Grid

A Water Smart Grid comprises innovative technology suites, including smart water meters, sensors, advanced modeling, water mapping, smart irrigation, etc. These are implemented based on a platform of "Water Cycle Traceability" to monitor the status of water quality, water quantity, and other factors. Smart Water meters would be able to send data to water companies several times a day rather than a few times a year. Additionally, a variety of sensors would be embedded throughout the supply, distribution, and treatment infrastructure for real-time, remote monitoring and management of key parameters, such as flow, pressure, temperature, quality, storage levels, consumption, and energy usage. (Hinchman et al, 2012) (Figure 13)

5.6.3 Smart Waste Management

The integrated model of Smart Solid Waste aims to maximize the renewable benefits of solid waste as a strategic resource while minimizing the long-term externalities associated with discarding waste. This technology touches on four separate phases of traditional solid waste management: (Lawrence and Woods, 2014)

- *Smart collection* – This phase includes Radio Frequency Identification tagging, global positioning system routing, and pneumatic tubes. (Figure 14)

- *Smart processing* – This phase comprises advanced material recovery facilities and mechanical biological treatment, and refuse-derived fuel production facilities.
- *Smart energy recovery* – This phase comprises waste-to-energy, waste-to-fuels, and landfill gas-to-energy.
- *Smart disposal* – This phase includes sanitary land filling, bioreactor landfills, and solar integration

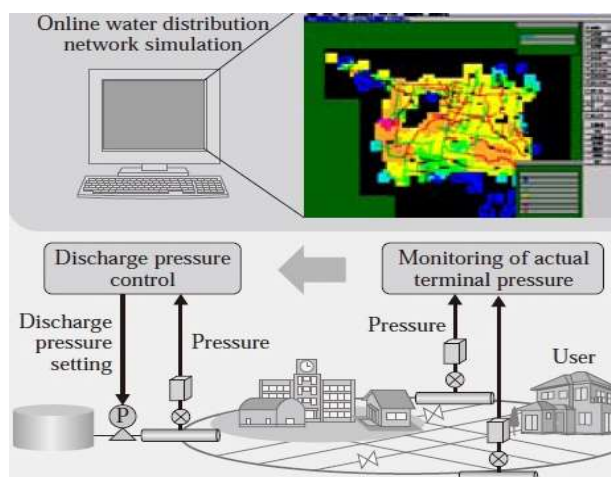


Figure 13: The system simulates the water distribution network in real-time using GIS and online pressure and flow measurements to calculate optimum pump discharge pressure and flow rate settings. Source: Hitachi, 2012

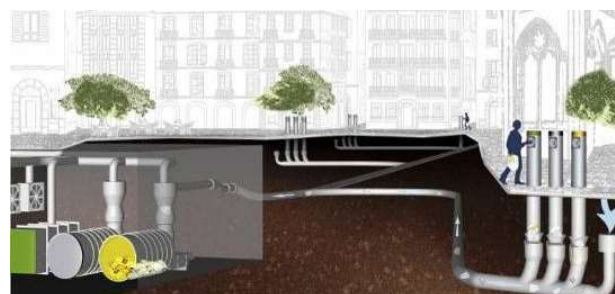


Figure 14: The Envac pneumatic waste collection systems are based on a network of pipes through which a powerful airflow is in charge to transfer the waste to the collection station. Source: ENVAC

6. The EU SET Plan

Alerted by the rapid quantitative and qualitative growth of the new Asian international technology centers, the European Union tries to protect its technological leadership in certain traditionally European competence fields, including energy and environmental technologies as well as transport issues, the technological development of which will be advanced under the SET program and will be tested in European cities. The SET plan is the technological pillar of the EU's climate and energy policy and will increase strategic investment in R&TD. The ultimate goal is to create a "low carbon economy" with the following targets compared to 1990 levels: (Barcelona City Council, 2012)

- 20% reduction in greenhouse gas emissions by 2020
- 20% reduction in global primary energy use by 2020
- 20% of renewable energy in the EU's overall mix by 2020
- CO₂ emissions reduction by 80% by 2050
- Economic growth and creation of jobs

In this paper we aim to focus on a range of innovative deployment strategies in two of the top-performing cities in Europe (Amsterdam and Barcelona) in their transformation into Smart Cities in response to the EU 2020 Strategy, with a focus on the ICT usage and coverage in various sectors of the city.

6.1 Amsterdam Smart City (ASC)

The Amsterdam municipality has developed "New Amsterdam Climate", which sets out the city's vision to neutralize all municipal organizations' impact on the climate by 2015 from the 1990 baseline, 40% CO₂ reduction by 2025, and locally produce one-third of energy needs using renewable sources by 2025, envisaging a 70-80% reduction in CO₂ emissions by 2040. To help deliver the 2025 goals, a scheme known as Amsterdam Smart City "ASC" project was initiated, which has grown into a broad platform with more than 70 partners that are involved in a variety of projects. Three points are central to all ASC activities: (Hirst et al, 2011) (Figure 15)

- *Platform* – ASC connects the needs of users, residents, government, and business.

- *Testing* – ASC can be perceived as a living lab that allows businesses to both test and demonstrate innovative products and services.
- *Open infrastructures, open innovation, open knowledge, and open data.*

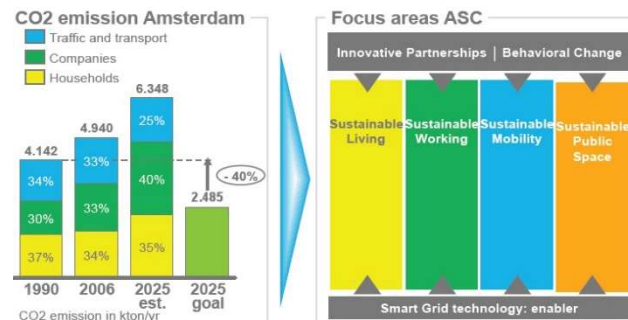


Figure 15: ASC focuses on four areas that correspond with the largest sources of CO₂ emissions in the city. Source: Accenture, 2011

6.1.1 Amsterdam Smart City Focus

The projects that are executed in Amsterdam can generally be divided into three categories: all relating on energy, connectivity, and data. The Amsterdam Smart City project comprises two phases as follows (Baron, 2013).

6.1.1.1 The First Phase (2009 - 2012)

During the first phase, the focus was primarily on collaborative models and creating insight into data for users, which resulted in usage reductions of around 12-13%. Examples of projects that demonstrate this phase are as follows: (Baron, 2013)

- *Climate Street* – In this project, Amsterdam will determine which technologies and approaches are the most successful to make the city's streets more sustainable on a large scale, and that will be achieved through a combination of initiatives such as sustainable waste logistics, energy displays, LED lighting, smart meters and energy management systems. Of the related changes in user behavior in the Climate Street project, the participation rates are: smart meter and displays: 80%; electric garbage collection:

90%; and sustainable logistics: 30 entrepreneurs.

- *Urban Eco-Map Application* – Through this application, citizens of Amsterdam will be able to view their neighborhood data through visual displays in the areas of transportation, energy, and waste and receive tips on ways to reduce a resident's carbon footprint. (Figure 16)



Figure 16: A city can use Urban Eco-Map to create awareness among its residents of carbon emissions' impact on their urban environment. Source: Cisco, 2009

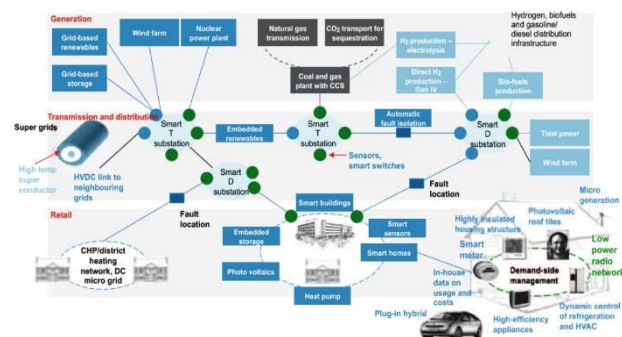


Figure 17: New West district contains 40,000 households, of which around 10,000 are served by Alliander's new Smart Grid. Source: International Energy Agency, 2012

6.1.1.2 The Second Phase (2012 - till now)

Focuses on possibilities for users to act through the development of smart infrastructures revolving around energy and connectivity. Examples of

projects that demonstrate this phase are as follows: (Baron, 2013)

- *Fiber-to-the-Home* – The fiber network has so far been rolled out in five districts in Amsterdam, including IJburg and others
- *Amsterdam Smart Grid* (Figure 17)
- *Smart Traffic Management System*. (Figure 18)



Figure 18: TrafficLink's SCM system optimizes the overall road capacity within a region and between two regions. Source:

<http://amsterdamsmartcity.com/projects/detail/id/58/slug/smart-traffic-management>

6.2 Barcelona

Barcelona is updating their energy plan to provide a new program up to 2020 to reduce energy consumption by 9%, reduce CO₂ emissions by 16%, and improve air quality. Barcelona's Smart City concept aims to increase citizens' quality of life, support more innovative business, make city management and maintenance easier, and enhance the development of a greener city. The Barcelona model is built around: (Barcelona City Council, 2012) (Figure 19)

- *Ubiquitous infrastructures*
- *Rich information*
- *The human capital of Barcelona.*

6.2.1 Barcelona Smart City Focus

The Barcelona Smart City project comprises vertical solutions (map of vertical projects) built upon horizontal enabling technologies (map of transversal projects).

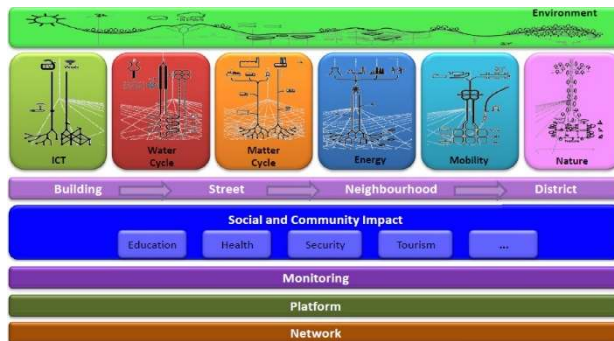


Figure 19: Barcelona City leaders understand the city as something dynamic and changing—a network of networks—as illustrated in their conceptual model. Source: Barcelona City Council, 2012

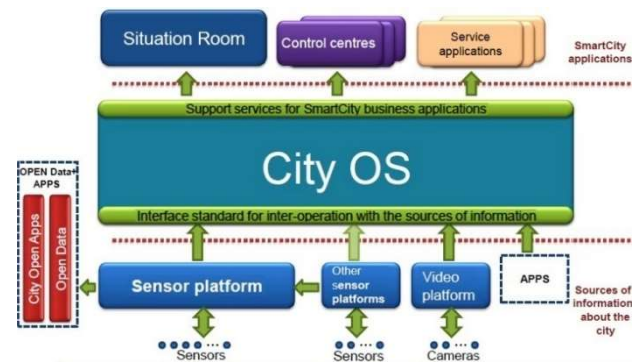


Figure 20: Barcelona is creating an efficient smart services delivery platform for citizens and municipal to improve urban services' management. Source: Barcelona City Council, 2012

6.2.1.1 Map of Transversal Projects

Examples of projects that demonstrate this phase are as follows: (Barcelona City Council, 2012)

- **New Municipal Networks** – Barcelona has a network of 325 km of fiber optics and a closed broadband infrastructure with 1 Gbps links that cover council related groups. Also, the municipality has extended their Wi-Fi network to allow permanent broadband throughout city streets.
- **Urban Platform (Including Sensor Platform, City Operating System, and Apps and Services)** – Applications in this platform are sensors in solid waste containers, street sensors to figure out occupancy of parking spaces, humidity sensors, urban metering (gas, water, and power), and control and manage traffic automatically. (Figure 20)
- **Intelligent Data** – This category includes open data, situation room, and city indicators measurements. Public data owned by the city council is made accessible to the public. The portal includes more than 300 categories of data grouped in 5 basic areas, including; territory, population, economy, urban environment, and administration. (Figure 21)

6.2.1.2 Map of Vertical Projects

Examples of projects that demonstrate this phase are as follows: (Department for Business, Innovation and Skills, 2013)



Figure 21: Central situation room for decision making and control. Source: Barcelona City Council, 2012

- **Urban Spaces (22@ District)** – The Smart City is being implemented for the first time in the 22@ District to use this experience as a blueprint for reforming other city's districts. Some projects being implemented at 22@ are: "Systems of Underground Service Galleries" for interconnecting the blocks and enabling service networks to be repaired or improved without the need for excavation in the streets; "New Fiber-optic Networks"; "New System for Centralized Public Climate Control", which involves savings at both the economic level and CO₂ emissions; "Automated Waste Collection System"; "New Electricity Network"; and "22@ Urban Lab."
- **Energy Saving Projects** – This category includes the rehabilitation of buildings to improve their energy efficiency through the development of an advanced system of integrated management that favors energy efficiency.

- *Water Distribution System* – Regarding this category, the Barcelona information system receives, in real-time, data from 200 control points, mainly flow meters and a few pressure sensors. (Figure 22)
- *Automated Waste Collection System* – In the 22@ District, the pneumatic and selective waste collection system has been operational since 2006.
- *Dubai Smart City* – To address the challenges and realize the Dubai Plan 2021's goals, Dubai has launched its Smart City Strategy, aiming to transform itself into the smartest city in the world over the next few years. The strategy features six key pillars and 100 initiatives on transport, communications, infrastructure, electricity, economic services and urban planning. Under the strategy, 1,000 government services are set to go smart by 2017. (Dassani et al, 2015)

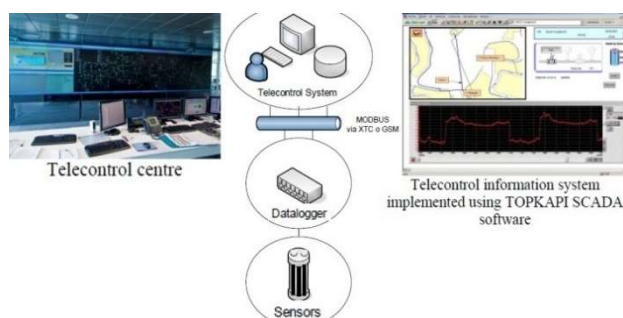


Figure 22: Tele-control of Barcelona Water Distribution System Using SCADA Software.
Source: Technical University of Catalonia

7. The UAE Vision 2021

His Highness Sheikh Mohammed bin Rashid Al Maktoum has launched a seven-year UAE National Agenda leading to the UAE Vision 2021. The UAE National Agenda includes a set of national indicators in the sectors of education, healthcare, economy, police and security, housing, infrastructure, and government services. These indicators are long-term, measure performance outcomes in each of the national priorities, and generally compare the UAE against global benchmarks. However, the government strategy has focused on the diversification of the national economy and increased investment in other sectors, including clean energy, advanced manufacturing industries, tourism, ICT, transportation, ports, freight, aviation, and space technology. In line with Vision 2021, Abu Dhabi's Economic Vision 2030, as well as Dubai's Plan 2021 and the Dubai Integrated Energy Strategy 2030, lead the drive towards economic diversification and sustainable development in their respective emirates. (UNFCCC, 2015)

8. Conclusion

First of all, we need to emphasize that the Smart City is a fuzzy concept and has no single template to define or build upon. A number of definitions for the term "Smart City" exist. One of the more widely used definitions is outlined by Giffinger et al who define the Smart City as "a city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent, and aware citizens".

Even though the term "Smart City" is relatively novel, the development of a Smart City can vary dramatically depending on the approach that is taken regarding policymaking for the urban growth of the city. Each city decides its own approach to becoming smart based on its own needs, objectives, and resources. The government has a serious role to play in developing an overall strategy and framework for a Smart and Sustainable City, which depends on assessing and defining the government objectives and its readiness to incorporate new solutions and exploring which solution would improve the city.

Based on the previous study and analysis, we can conclude a common framework for transforming cities into smart ones:

- First, each city has to define its own objectives and needs. In this case, let's say that city leader is keen on promoting sustainability.
- After that, each city must check its indicators, which are appropriate and matching its objectives and define which sectors aren't ranked high. This means that the government

should analyze issues for the entire organizations, department by department, or tackle a single department, such as smart infrastructure, smart buildings, etc.

- Then, they should detail the physical components for the department/departments that aren't ranked high.
- Last but not least, city leaders have to seek out the best practices in other cities and how those cities overcome the obstacles in the department. The city needs to tackle and

come up with appropriate solutions for their case.

Finally, we have to highlight that the government needs to develop strong partnerships with the private sector, which can deliver sophisticated solutions. Also, the government has to make the data open for the public and make it easy for the public to make and contribute their own data. The Smart City vision can't be achieved without the participation of the public and their contribution with the government in making decisions.

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