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International Case Studies of Smart Cities

Santander, Spain

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Institutions for Development Sector

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SANTANDER

SPAIN

IDB-KRIHS Joint Research

IDB

THE REPUBLIC OF KOREA

KRIHS
Korea Research Institute for Human Settlements

GDPC
Global Development Partnership Center

Abstract

This case study is one of ten international case studies developed by the Inter-American Development Bank (IDB), in association with the Korean Research Institute for Human Settlements (KRIHS), for the cities of Anyang, Medellin, Namyangju, Orlando, Pangyo, Rio de Janeiro, Santander, Singapore, Songdo, and Tel Aviv. At the IDB, the Competitiveness and Innovation Division (CTI), the Fiscal and Municipal Management Division (FMM), and the Emerging and Sustainable Cities Initiative (ESCI) coordinated the study. This project was part of technical cooperation ME-T1254, financed by the Knowledge Partnership Korean Fund for Technology and Innovation of the Republic of Korea. At KRIHS, the National Infrastructure Research Division coordinated the project and the Global Development Partnership Center (GDPC) provided the funding.

The case of Santander as an object of study in the field of smart cities and as an international reference is known for the widespread deployment of devices, which makes it unique in the world as a testing ground. This, coupled with the diversity of services that are integrating technology throughout, means that today, the city, through its council, the university, and the successful tenderers for municipal services, is participating in more than 15 international projects. The next step, already underway, will be the integration of all smart services (e.g., water supply, solid waste collection, street lighting, and public transportation) into a single smart platform that will allow them to interact with each other and represents a step toward efficiency and smart city management.

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Keywords: smart cities, technological innovation, information and communication technologies, SmartSantander, public transport, waste collection, citizen participation, Internet of things, open data, sensors, Santander

With the collaboration of:

AYUNTAMIENTO DE SANTANDER

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Executive Summary

As a smart city, Santander can be considered a pioneer reference case for several reasons. The main reason is the widespread deployment of connected devices, both fixed and mobile, throughout the city thanks to SmartSantander, a project financed by the European Community-VII Framework Program that was developed from 2010 to 2014 and led by the University of Cantabria and Telefónica I+D. Its aim was scientific research on the future of the Internet and machine-to-machine communications. Thanks to the early experience of this project, the 14,000 devices installed at that time, and the municipal innovation policy, Santander developed a number of projects using both public and private funding. These projects have placed the city at the forefront of innovation in the field of smart urban management. Today there are some 20,000 devices installed. As a result, Santander is one of the largest living laboratories in the world. It is also one of the few cities that permitted operations that cover the entire city.

Some important features of the SmartSantander project are:

- Political leadership by the mayor of Santander, who also chairs the Spanish Federation of Municipalities and Provinces and the Spanish Network of Smart Cities (RECI), which represents 62 cities.
- Integration of its Smart City Project with the city's strategic planning (Strategic Plan for Santander 2010–2020) and good sectoral planning thanks to the Santander Master Plan for Innovation and the Santander Smart City Plan.
- Close collaboration between the Santander City Council, the University of Cantabria, and the private sector.
- Step-by-step evolution of its experience as a smart city involving installation of sensors, subsequent progressive implementation of the smart and sensor concepts into various urban services, such as water provision, urban solid waste collection, public transportation, and street cleaning, and the current process of unification with the Integrated Operation and Control Center, part of the Santander smart city platform.
- Its unique sensor deployment within the city and its character as a live urban laboratory.
- Competitiveness in the European and worldwide context in funding of public research projects.
- Existence of general innovation management that depends directly on City Hall, which coordinates Santander's Smart City project and integrates its information and communication technologies (ICTs), and innovation in all areas municipal management, including e-administration, open data, transparency, and more.
- The application of an integrated and integrating focus to innovation in an urban context that shares Santander's characteristics, such as a population of fewer than 180,000 inhabitants, to enable the development of new experiences in areas such as e-administration, tourism, energy saving, mitigating climate change, and public participation.

From an urban development standpoint, the main challenges facing Santander in terms of consolidation and sustainability of a project such as the Smart City Project are communication with a didactic focus on the

project and consolidation within the fabric of local business.

From a technical standpoint, the start-up of the future **Integrated Operation and Control Center** provides a great opportunity and an important challenge. The opportunity is that smart city management will be generated by the transition toward an integrated, crosscutting system. The challenges lie in integrating the technologies deployed to generate, communicate, and handle data, and/or in using the Integrated Operation and Control Center and its technical department as a structure that supports the local administration's decision-making process.

The most important results of the Smart City Project include improvement in the quality of citizens' lives and optimization and reduced costs of the urban services provided, as well as positioning the city as a world leader in the field of innovation.

In the medium term, the project will enable complete interaction between the information generated by urban services such as water supply, transportation, lighting, traffic control, and others within a single platform for use and storage. Moreover, the public will have a more active role in the project. Instead of being mere users of tools, they will generate tools. Citizens will be able to determine what is needed to improve their quality of life and what role technology will play in bringing it about.

In summary, Santander is a smart city in transition from a vertical to an integrated management model, in which its smart city platform will be able to generate intelligence derived from information collected from its various city services. Moreover, the city is a unique area where the simultaneous deployment of technological devices has created an atmosphere where experimentation and service delivery can coexist.

Santander, Spain

1. Introduction

1.1 Vision of the City

Santander is the capital of the Autonomous Community of Cantabria, Spain. The municipality has a total surface area of 34.8 km² and a population of 175,736 inhabitants (December 2014). Its municipal budget for 2015 is more than €188 million. The information that follows will provide details on the city's geography, economy, and environment.

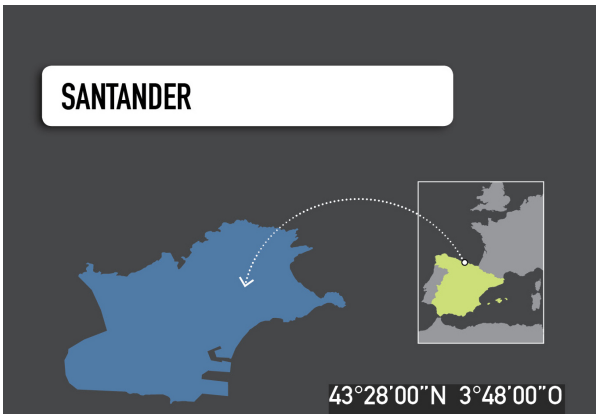
Image 1. Limits of the Municipal Area of Santander

Source: Authors' elaboration.

1.1.1 Geography and Society

Geographically, Santander is situated in the center of Spain's north coast. To the north and east is the Bay of Biscay, and to the south lies Santander Bay. Its geographical coordinates are 43°28′00″N 3°48′00″O.

Image 2. Location of Santander



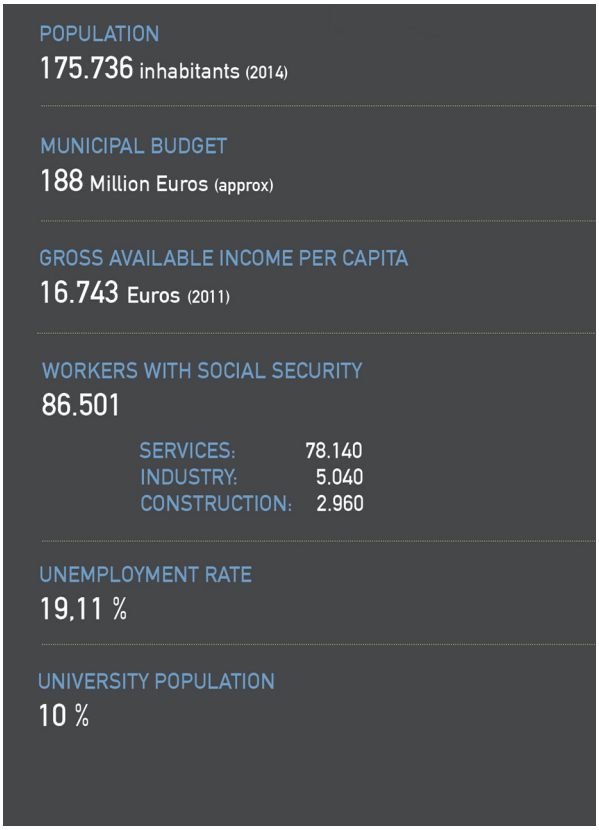
Source: Author's elaboration.

- It has an oceanic, or Atlantic, temperate, humid climate. The average temperature in the coldest month is about 9º C; in the warmest month it reaches approximately 20º C, and annual rainfall is around 1200 mm/m² (State Meteorological Agency, www.aemet.es).

Its coastal location makes it especially vulnerable to the effects of climate change.[1] The most immediate effects are caused by the increase in extreme maritime phenomena and their impacts on urban infrastructure and beaches. The city has already established protocols for action against these phenomena, and adaptation to climate change is an area in which the city can integrate its experience as a smart city.

[1] At the beginning of 2013, Santander suffered the effects of several storms considered to be extraordinary maritime phenomena http://www.europapress.es/sociedad/noticia-olas-10-metros-causan-numerosos-destrozos-mobiliario-urbano-garajes-locales-santander-20140202190328.html

Image 3. Main Data



Source: Author's elaboration based on ICANE data.

- The metropolitan area includes other municipalities, such as Camargo, El Astillero, and Santa Cruz de Bezana, and the population is around 280,000 inhabitants for the entire area. The population can grow as high as 380,000 in the summer season because Santander is an important tourist destination.
- Santander has one of lowest crime rates in Spain. There were approximately 15 penal infractions per 1,000 inhabitants in the first six months of 2015. Although this might seem high, only 10 percent were serious crimes, the rest being petty crimes.
- It is a university city that enjoys the presence of:
    - The University of Cantabria; for the academic year 2013–14, it had a community of more than 16,000 students, lecturers, researchers,

and service and administrative personnel.

- The Menéndez Pelayo International University, which holds summer courses from June to September. In 2014, it offered 150 courses with more than 6,000 students in attendance.
- The European University of the Atlantic, which opened in 2014 with 350 students.

1.1.2 Economy

- Gross per capita income for 2011 was, according to ICANE, € 16,743.[2]
- The unemployment rate in the first three months of 2015 was 19.11 percent.[3]
- As for economic activity, in June 2015, of the 86,501 workers who paid national insurance, 78,140 worked in the service sector, followed by 5,040 working in industry, and 2,960 in construction.
- Santander's economy is largely based on services, which is clearly reflected in the distribution of economic activity by sector. The public study containing the most economic data grouped by category is included in the General Urban Plan approved in 2012.[4]
- Santander has an important port with activity in the transport of goods, chiefly coal, scrap, cereals, and vehicles, and in passenger transport. A regular line runs between Santander and Plymouth, and the port receives around ten cruise liners per year.
- The Marqués de Valdecilla University Hospital is another of the city's assets. It has more than 900 beds and in 2014 had 35,831 admissions. Excluding external services such as cleaning, catering, security, and maintenance it employs more than 4,500 workers (http://www.humv.es/estatico/docs2011/humv_memoria_2010.pdf).

1.1.3 Environment

- The main sources of atmospheric pollution are road traffic and domestic heating systems. Nevertheless, the air quality is good and has improved over the last two years. There are only a few periods in which the ozone levels become excessive during the intensely hot summer months. In addition to the sensors installed by the City Council thanks to the SmartSantander Project,[5] there are two regional government air quality monitoring stations and several information screens throughout the city that monitor the ozone levels. This information can be obtained at http://www.airecantabria.com/. As part of the European Project "TILAS" 15 PM10 (particles of less than 10 micrometers), high-precision particle sensors have been placed throughout the city to measure wind speed, temperature, and humidity. The main sources of noise pollution are associated with high traffic density on some routes during the week and nightlife-related activity on weekends.

[2]http://www.icane.es/c/document_library/get_file?uuid=bd00b9a2-8deb-447f-bc4b-bf1ad4957ccf&groupId=10138

[3] http://www.icane.es

[4]http://portal.ayto-santander.es/pgou/a_inf_1/1_anexo1_parte_1.pdf

[5] SmartSantander is funded by the European Community-VII Framework Program, carried out from 2010 to 2014 and led by the University of Cantabria and Telefónica I+D. Its objective is scientific research on the "Internet of the future" and machine-to-machine communications.

- In 2002, the Santander Bay Integrated Water Treatment Plan was introduced. It has definitively improved the municipal area's environment by eliminating approximately 80 outfalls within the water body, which is one of the city's principal environmental and scenic resources.
- Santander's water supply service has around 100,000 contracts (a user can have several contracts for different service points). In Cantabria, the average consumption per inhabitant in 2014 for all uses was 161 liters per day, which is much higher than the national average of 137 liters.
- Based on the latest validated data on urban waste available from the National Statistics Institute (INE), which are from 2012, Santander generates 0.910 kg/inhabitant/day of mixed organic residue, 0.060 kg/inhabitant/day of paper-cardboard waste, and 0.026 kg/inhabitant/day of containers. These three values are below the national averages of 1.070, 0.063, and 0.037 kg/inhabitant/day, respectively.
- In Santander, there are a variety of landscapes due to its location and topography. The rural scenery, the bay and the marshes, the beaches, the industrial landscape, and the cliffs are examples. The city has two distinct facets: an urban one to the south and along the bay, and another in the north, each with its own identifying features.

1.1.4 Information and Communication Technologies

- In 2012, Santander had 53,266 broadband landlines, representing a market penetration of 30.4 lines per 100 inhabitants; the national average that year was 24.7 lines per 100 inhabitants.[6]
- In 2012, Santander had 93,983 landlines, representing a market penetration of 53.7 lines per 100 inhabitants, a much higher number than the national average that year, which was 40.8 lines. There are no official data on mobile telephone lines at the municipal level.
- Since 2009, Santander has housed the Scientific and Technological Park of Cantabria, a new 237,000 square meter enterprise zone situated on the outskirts of the city. Its orientation toward activities based on non-polluting innovation and technology is a factor to be considered when developing a smart city project. The park currently accommodates more than 20 medium-sized businesses that carry out activities in telecommunications, biotechnology, information technology, and energy and environmental management (www.pctcan.es/pctcan/empresas/).

1.2 Current Challenges for the City and Evolution of the Santander Smart City Project

The planning that was carried out to guarantee convergence between the challenges the city faced and its Smart City Project has had important impacts. The planning documents that were compiled enabled the city to keep track of its needs and respond to some of them through its Smart City Project. The most relevant of these documents are the 2020

[6] http://data.cnmc.es/datagraph/jsp/inf_men.jsp

Strategic Plan, the Master Plan for Innovation,[7] and Santander's Smart City Strategic Plan.[8]

1.2.1 Current Challenges for the City

Santander, along with more than 200 bodies and citizens, analyzed its medium-term future from 2010 to 2012. The result was the Santander Strategic Plan 2010–2020.[9] Through 30 priority actions, it proposes a city model whose development should be based on innovation and culture.

The general idea of developing Santander through innovation, and especially as a smart city, has enabled the business and entrepreneurial fabric to be revitalized. It has led to positive developments, such as internationalization of the city, attraction of investment, consolidation of research and development activities, and more efficient urban services. The Santander Smart City Strategic Plan, which sets out the priorities of the Smart City Project over the next four years, has just been written. Its horizon is 2020, an appropriate time frame for a field as dynamic as technology.

In the cultural realm, the Smart City Project is providing a great opportunity for Santander thanks to two important new cultural centers that will soon open their doors. These are the Botín Center and the Associated Center of the Reina Sofía Museum. They will have an international projection, enabling the City Council to advance along the smart city path through, among other initiatives, the Cultural Ring and the Santander Creative Foundation.

From the spatial perspective, the city faces two important challenges common to many European cities. These are the ongoing transformation of its maritime zone and the integration of the city's railway system, which is currently a barrier to urban cohesion. From the social standpoint, reducing unemployment and serving the aging population are high-priority challenges. With respect to the environment, reducing the consumption of resources, especially energy, is the focus of significant efforts.

1.2.2 Origin and Evolution of the Santander Smart City Project

In recent years, Santander has been implementing new, smart models of service delivery through the creation of new infrastructure and communication networks. The 2010–2020 Strategic Plan reflects the municipal strategy of innovation, which is, along with culture, one of the two pillars on which it is based.

The Santander City Council led this metamorphosis, with the collaboration of the University of Cantabria and local, national, and international companies.

The "smart" experience began in 2010, with selection and funding of the SmartSantander project by the European community, through the VII Framework Programme. This project, which was led by Telefónica I+D and the University of Cantabria with the support of the Santander City Council and the regional government of Cantabria, attracted the participation of 15 public and private partners from Spain, Italy, Serbia, the United Kingdom, Germany, Greece, Denmark, and Australia. The project's budget was €8.67 million,[10] €6

[7]http://portal.ayto-santander.es/documentos/plan_director_innovacion.pdf

[8]http://portal.ayto-santander.es/portal/page/portal/inet_santander/%5Bhtdocs%5D/pdf_contenidos_diversos/2.%20Plan%20Estrategico_Sant_Smart_City.pdf

[9] http://www.planestrategicosantander.com/

[10]http://www.europapress.es/cantabria/noticia-arranca-proyecto-smartsantander-convertir-capital-cantabra-ciudad-inteligente-20100908183142.html

million of which was provided by the European Union and the other €2.67 million by the participating partners. The principal partner of the project, Telefónica I+D, which made the payments to the participants, administered the community funds.

Based on the idea of machine-to-machine (M2M) communications and interaction between devices and sensors, the SmartSantander project enabled the installation of 12,000 devices throughout the city. This provided the opportunity to take on one of the first experiences of the smart city. It also allowed the city to become a live laboratory, providing a unique environment for experimentation of real interaction with urban service delivery.

Starting with the seed of SmartSantander, the City Council decided to gradually integrate M2M communication technologies into some aspects of municipal administration, such as traffic, urban waste collection, and smart management of the integrated urban water cycle. In this way, smart services were implemented within a vertical management model in which the relationship among them is still limited. Gradually, more innovation clauses will be included in the tenders of all essential public services.

Presently, the Santander City Council is on the verge of contracting ICT services for the Smart City platform and starting up the project's technical office. The amount of the contract is €2,238,000 over four years, to be funded by the City Council. The platform and its technical office will enable crosscutting management of city services, the relationship between them, and technological integration of all new contracts. Henceforth, when an incident is reported, such as a burst pipe in the water supply service, after validation from the personnel responsible, it will be possible to generate the pertinent warnings automatically for the local police, municipal service providers, and users. Traffic will be rerouted automatically via alternative roads, or trash collection services will be modified to avoid the area where the incident is occurring.

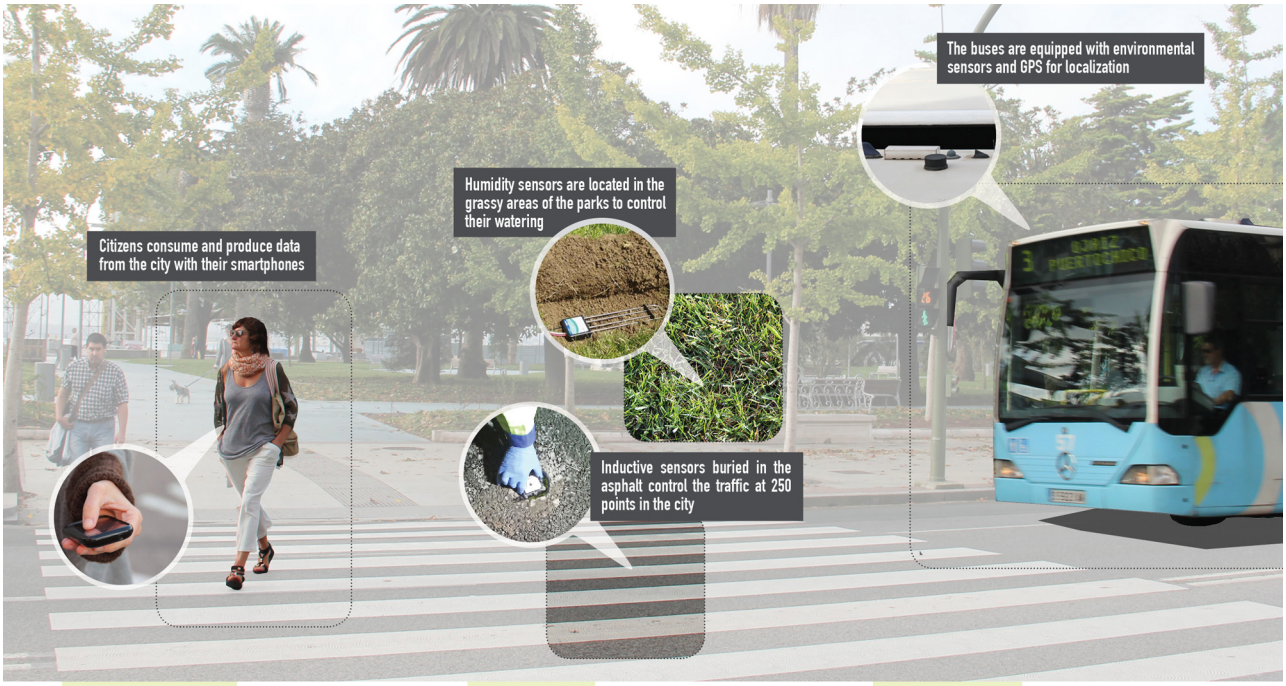
The city now has approximately 20,000 devices of three types: static, dynamic, and participatory.

The principal landmarks in the evolution of the project are the following:

- 2010: September, the SmartSantander project began, funded by the VII Framework Program of the EU.
- 2011: Future Internet Award for the SmartSantander project (awarded by the European Union, through ceFIMS [Coordination of the European Future Internet Forum of Member States]).[11]
- 2012: Santander founded the Spanish Network of Smart Cities, was named second Smart City by the IDC, and approved the Master Plan for Innovation.
- 2013: public tender for the management of municipal waste, which included, for the first time in a public services contract, the implantation of IoT (Internet of Things) technology. The Smart Water research project began, and the Smart City Demonstration Center opened to the public in the Pronillo district.
- 2014: implementation of the electronic bill (e-administration) and startup of the Open Data website (http://datos.santander.es/) and the Transparency website (http://transparencia.santander.es/).
- 2015: approval of the Santander Smart City Strategic Plan and contract for the Santander Smart City Platform.

[11]http://www.rcysostenibilidad.telefonica.com/blog/2011/05/27/la-comision-europea-reconoce-al-proyecto-smart-santander-con-el-future-internet-award/#.VjCXZbcvfIU

Figure 1. Types of Devices Installed



Santander is currently working alongside 220 partners throughout Europe on developing 15 innovation projects with a total budget of 61,144,572 euro provided by the European Union. The city's participation in these projects has been funded by the European Commission in the amount of € 1,537,266.

2. Range of Services

As mentioned above (Section 1.2.2), the city today has 20,000 devices of three types:

→ **Static**: located at different fixed points in the city, utilizing different urban furniture. The data collected are processed in the management server for later treatment by the different applications and tools to generate predictive models. Some examples of this type include sensors to detect available parking places (some 400 in the city center), humidity for optimized watering in green zones, filled trash bins, to measure water quality or monitor environmental parameters, such as noise, temperature, and CO_2 .

Image 4. Parking Sensor before Installation and Density Sensor during Installation

Image 5. Detail of Mobile Sensors on Top of the Cab of a Municipal Bus

- → **Dynamic**: installed in moving elements, such as public buses, parks and gardens, vehicles, taxis, or trash collection vehicles. These enable environmental and traffic information to be collected at numerous points within the city. They provide information about the state of traffic and feed data to the apps available to the citizens.
- → **Participatory**: citizens themselves collect data or incidents that are occurring in the moment at the point where they are passing. The "City Pulse" app[12] (www.elpulsodelaciudad.com/) permits them to contribute actively to the management of the city by reporting incidents they find on the streets of Santander (potholes, unmaintained benches, broken trash bins, and so on) and enclosing photos of these. The citizens can follow the state of the incident at any time and the stage of processing by the City Council.

With respect to the connectivity infrastructure, information is gathered or sent to the devices through "a combination of wireless, mobile and fixed infrastructure, depending on the needs in terms of mobility, bandwidth, and latency of the specific application. In some cases, wireless and mobile networks will be the only ones available. In general, the sensors transmit information using light protocols to coordinators or gateways, which in turn route data through mobile or fixed lines and deliver them to databases and platforms that facilitate the delivery of services."[13]

The smart services currently available throughout the city can be classified according to the scheme proposed by those who are managing the work.

2.1 Transport and Mobility

Sensors that measure the traffic entering the city have been installed, and more than 200 inductive sensors also measure traffic density. Ten panels have been installed along 10 routes in the city center, which provide real-time information to drivers before they enter a street where a free on-street parking space is available; panels provide information about nearly 400 parking places.

The city also has tags or stickers installed at its bus stops that provide data about the municipal bus service lines, stops, waiting times, and other information. In the SmartSantanderRA app, more detailed

[12] https://play.google.com/store/apps/details?id=com.eu.smartsantander.participatorysensing&hl=es

[13] Extraído del Plan Director de Innovación http://portal.ayto-santander.es/portal/page/portal/inet_santander/ciudad/plan_de_innovacion

information is available about nearby bus stops, the bus lines that serve each stop, the arrival time of the next bus, and its current location.

The app also contains information about traffic, bicycle hire points, taxi stops, or underground car parks with real-time data about availability in each of them. Therefore, it is a great tool for promoting multimodal mobility, the paradigm of urban sustainability.

Lastly, five information panels have been installed at selected points in the city, with real-time information about the traffic on the principal routes. This enables users to choose among alternative routes to reach their destinations, thus reducing travel times and actively contributing to the reduction of CO_2 emissions (less consumption of fossil fuels=lower emissions of CO_2). There is also an application for paying in the pay- and display-parking zone (Ordenanza Limitación Aparcamiento, or OLA).

All of these have generated some benefits both in terms of the functioning of the system itself and of public satisfaction. Although the use of GPS is common in monitoring fleets, the advance for Santander with respect to the municipal bus system lies in the greater quantity and quality of information available to the citizens, who now know, in real time, how long they must wait, the distance, and the line to catch to get to a specific point (quality of life).

2.2 Public Safety

Public safety is one of the least developed sectors in the Santander Smart City Program. The reason is that public safety and criminal activity are not a real problem in the city, as this urban area has one of the lowest crime rates in Spain.

Nevertheless, security cameras have been installed throughout the city. They are viewed, stored, and managed in the control center of the local police. There are 157 cameras installed and distributed in 15 groups or systems corresponding to municipal buildings and infrastructures. The buildings where most of the cameras are installed are the Sporting Events Center, the Exhibition and Fair Center, and City Hall. To date, none of the cameras records audio, and the vast majority are fixed. In fact, only 19 of the 157 existing cameras are motorized. Currently, the whole security camera project is being updated. Centralized software is being installed to manage all of the city's security-related images. IP cameras are being installed, or the current ones are being adapted so that all of them send their images to City Hall's data center (information technology of the General Director for Innovation) as well as to the control center of the municipal police. There, they will be stored and treated in a single, centralized system available for storage and exploitation of data.

Finally, the city's taxis, thanks to the panic buttons installed, can create emergency warnings that alert the local police control center, where the locations of all taxis can be seen.

2.3 Emergencies and Civil Protection

A proprietary communications network is being implemented in Santander for emergency services, such as the fire brigade, police, and civil protection. These emergency services will have a system available with maximum coverage in the city, all integrated within a single system with a common coordination channel, which did not previously exist. Moreover, new terminals are being installed with the latest technologies that will enable individual vehicles and police officers to be located. Firefighters will have equipment that provides coverage even in those areas without it, so that they can be located, for example, inside buildings.

Work is also is being done on an experimental basis to enable automatic integration of warnings of extreme maritime phenomena as a way to adapt to climate change.

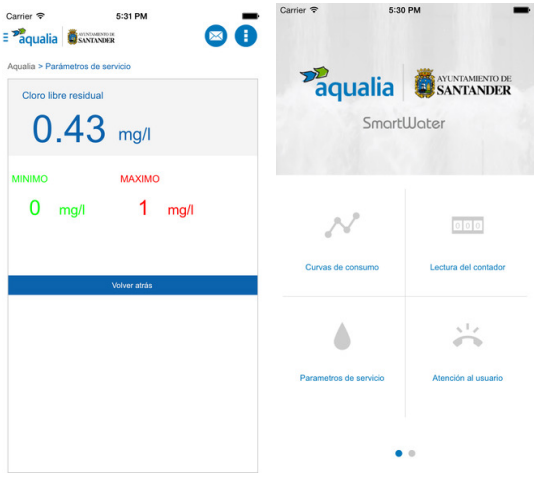
2.4 Environment

The management of the integrated urban water cycle, as part of the environmental management of the city, is another area where smart solutions are taking hold in Santander.

The first phase of the smart water project has been finalized. It consists of the installation of 1,000 remote domestic meter-reading devices, as well as network flow sensors and water pressure and water level sensors in the main sewer. These provide precise knowledge of the functioning of the water supply system and the sewerage system in a neighborhood of the city (Nueva Montaña) both at general and a user level.

As a complement, a mobile application has been created, called SmartWater, through which users can access real-time information about their consumption, water quality (pH and turbidity) or the pressure on entry into the home (one of the most frequent supply problems in a hilly city like Santander). The rest of the citizens can use the app to reduce or stop service, change the name on the contract, or receive alerts, such as programmed water cutoffs or interruptions in supply, or to find information about water quality, and others.

Image 6. Examples of the SmartWater Application Menu



In the second phase of the SmartWater project, the experience was extended to the central district of the city with the installation of 1,220 remote reading devices and sensors, enabling the network pressure or water quality to be monitored. Currently, nearly 9,000 citizens are benefiting from this pilot project. The intention of the project, in collaboration with the service provider, is to extend it to the whole city, thus balancing supply and demand and adapting to current and future climate change conditions.

The management of solid waste is another important feature of municipal environmental management in Santander and another area in which true smart city strategies are being implemented. The project has deployed more than 3,000 devices that provide real-time knowledge about the state of waste disposal points (situation, levels of filling, what has been done about them, service incidents, and so on), GPS monitoring of the works, and mobile sensors in the collection vehicles showing information about air quality, temperature, humidity, weight monitoring of container in trucks, and others. Moreover, volumetric sensors have been manufactured and installed in all recycling collection containers (paper, cardboard, and glass), and tags have been affixed to all of the trash bins, both recycling and organic waste containers.

This contract, awarded in March 2013 for a period of 10 years at a cost of €15.9 million per year, includes the anticipated development of an application that will provide information on all the necessary details about the most recent cleaning of the containers, replacement and substitution of trash bins, vehicle routes, fuel consumption, and assignment of personnel.

Finally, there is a wide deployment of static and dynamic environmental sensors, which enable real-time monitoring of temperature, humidity, precipitation, light levels, and noise. The data can be consulted on the webpage http://maps.smartsantander.eu/.

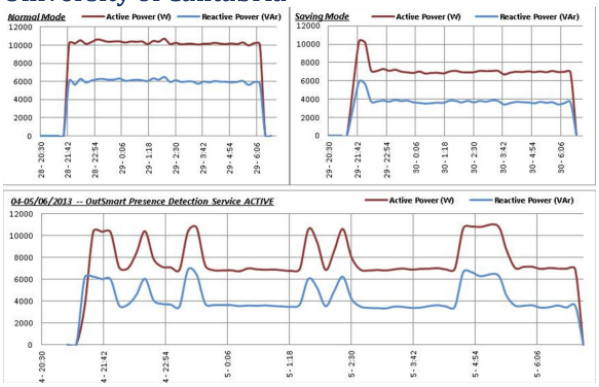
2.5 Energy Efficiency

The greatest advances in terms of energy efficiency achieved in Santander in relation to the Smart City Project have been and are currently being produced in the public street lighting service.

The transformation of the service that is occurring now is attempting to save 65 percent in the consumption of energy for outside lighting. Through a contract aimed at energy service companies, a total investment of some €14 million will be made to substitute 22,700 conventional lamps with LED technology, which will enable the lighting intensity to be varied depending on the position and the time of day, and complete interconnection with the Santander Smart City Platform and the rest of the services. The final result will be a saving of around €1.4 million per year and a significant reduction in CO_2 emissions due to the lower energy consumption. (In Spain, an important proportion of the energy consumed comes from fossil fuels, especially coal, diesel, and gas, which generate significant greenhouse gas emissions.)

Pilot projects have already been undertaken in two areas of the city. The installation of LED lights and presence detectors are permitting real data to be gathered about savings in consumption and pedestrian traffic.

Figure 2. Energy Consumption by System, University of Cantabria



Note: The three graphs represent the consumption of a traditional illumination system (above left), a saving mode system (above right), and an adaptive illumination system with presence detection (below).

2.6 Participation and Communication with the Public

This could be said to be another strong point of Santander's Smart City Program. The city now has information, communication, and public participation tools. All of them enable citizens to be informed about the city's main parameters, but they also improve the possibilities in sectors such as tourism.

The main active projects in this field are:

- Ten new apps in the "Mobile Santander" package. They include SmartSantander RA, which contains a wide range of useful information on city life (information about traffic, cultural activities, shopping, urban buses, public bicycles, and more) available through augmented reality, or e-park, which enables payment of car parking in OLA pay and display zones. Among the group of 10 applications is

The City Pulse.[14] As the name implies, it permits real-time information to be obtained about Santander's vital signs (temperature, traffic, news, parking info, etc.). It also allows citizen to communicate all types of incidents to City Hall and to be informed about the state of internal processing until resolution.

Image 7. Example of an Incident Generated through The City Pulse

- Santander's Open Data website (http://datos.santander.es/), which promotes transparency with the citizens, provides a positive ecosystem for entrepreneurship and business development in sectors with high technological value added. It provides an extensive catalogue of free open access data (85 datasets and 1135 resources), grouped into six categories: transportation, demography, public sector, commerce, society and welfare, and urban planning and infrastructure. As a practical example, a private citizen developed the application T.U.S Santander.[15] Some local businesses, such as Alter Geosistemas and CIC, have even integrated the city's open access data into commercial applications.
- Santander's municipal transparency website started up in January 2015 and has developed thanks to an agreement with Microsoft that has enabled the city to use this useful tool at no cost. In the current circumstances dominating the Spanish and European sociopolitical panorama, with high levels of dissatisfaction with political activity, distrust, and a significant erosion of trust due to cases of corruption, this website attempts to narrow the distance between citizens and public figures. The website www.transparencia.santander.es contains detailed information about Santander's international municipal administration transparency indicators (ITA) and the evolution of the municipal budget by area and month.
- Santander City Brain (www.santandercitybrain.com)[16] is another tool that promotes dialogue between managers and citizens through the creativity of the latter. Competitions are held in which a challenge is proposed. The most recent one solicited ideas for improving Santander as a tourist destination. The best ideas, those that receive the most

[14] http://www.elpulsodelaciudad.com/ Incidents of all types can be consulted.

[15] This application provides information at all times about wait times of Santander's urban buses. It can be consulted by bus line, by bus-stop number, or by selecting a stop on the map.
The state of the public bicycle service, the municipal, interurban, and interprovincial bus timetables can also be consulted, as well as the next departures and arrivals at Parayas airport.

[16] This page enables proposals about any aspect of the city to be collected. The latest examples were in urban planning, tourism, promotion, education, and others.

votes by the users, are rewarded. There are 1,982 registered users and 1,211 shared ideas. To date, six competitions have been held, but the platform permits contributions and proposals at any time. For example, Santander's Tourism Advisory Panel is analyzing the five winning ideas of the competition related to tourism in the city for their possible inclusion in the 2015–2020 Tourism Plan.[17]

- The demonstration center in the Pronillo neighborhood, started up in collaboration with Telefónica, is a visitor space envisaged for interested citizens to find out about the characteristics and possibilities of Santander as a smart city. With more than 2,000 guided visits to date, it enables the public to physically see the main devices installed and their applications and facilities. It is considered an important mechanism to promote public acceptance of the Smart City Project through hands-on knowledge, contributing by counteracting the logical lack of familiarity with the concepts and technological terminology.

[17] The five ideas were: installation of panels at the traffic light-controlled zebra crossings with tourist information about the city, promotional videos and advertisements about activities in the taxis through installation of tablets, dramatized visits to the Magdalena Palace, cooking courses in the Esperanza Market, and Santander live (webcam with real-time emission at distinct sites in the city). More information is available at http://www.santandercitybrain.com/

3. System Configuration

3.1 General Information

Today, the city of Santander is taking steps to change from sectoral and partial implantation of IT technologies to integration and interoperability of most municipal services. Santander's Smart City Platform will become as similar as possible to a so-called Integrated Operation and Control Center.

After five years of experience, important advances have been achieved in areas such as the management of water supply, urban waste, traffic, and public transportation, although the interoperability of these services has not become generalized. To date, the only contracts for provision of municipal services in which the implantation of IT technologies is required are for urban trash collection and street lighting. In others, such as water supply, the integration of IoT technologies is voluntary and is linked to collaborative research agreements with the University of Cantabria.

From now on, and thanks to the technical office foreseen in the contract of the platform, City Hall will have the necessary advice to introduce the integration of IoT technologies as a prerequisite among the conditions for tender in city services. Thus, it will be adopting a strategy of confluence, integration, and interoperability.

3.2 Level of Integration and Interoperability

Until now, there has been no dialogue among the city's systems in terms of urban management, other than some specific pilot projects. Despite this, the local authorities have a smart city project which is sufficiently mature to enable it to define its needs concisely when contracting Santander's Smart

City platform (technical conditions for contracts are available in the annexes).

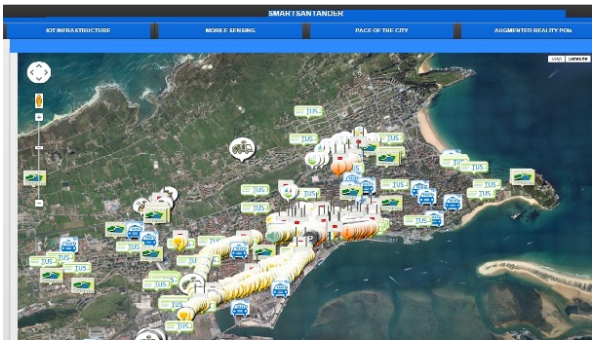
Today, there are distinct independent control centers, operated by both service-providing businesses, such as FCC Aqualia in water supply or Ascan-Geaser in trash collection, and different departments within the City Council itself, such as the local police control center in public security and the traffic control center in mobility.

The Municipal Data Processing Center houses the servers that store the data and technological services of the City Council. This center falls under the Director General for Innovation, responsible for Santander's Smart City project. Three municipal technicians are currently in charge of running it.

The personnel in charge of the various municipal areas exchange information and share documents through their own intranet, or IT network, working meetings, emails, and phone calls.

The INCISIS system is used to manage and resolve municipal incidents. It automates the assignment of tasks, sending alerts via email to the corresponding offices (parks and gardens, public works, water service, and others). On top of this system, which existed before the city's Smart Program, the City Pulse application was connected. It enables citizens to post their own incidents.

Image 8. Deployment of Devices throughout the City



Source: Author's elaboration based on http://maps.smartsantander.eu/.

With respect to the foregoing, all of the data obtained through more than 20,000 devices deployed, and some of the services, such as trash collection, are stored in a single repository (in the cloud), the Fi-Ware platform. This provides an opportunity to create intelligence in management, interrelating data from various vertical urban services, as has been done on different occasions through challenges in hackathons. Nevertheless, the lack of personnel assigned exclusively to the project, the absence of protocols, and the lack of flexibility of the administrations themselves will not allow this transition until Santander's Smart City Platform becomes available. Currently, real-time information can be consulted for Santander at the address http://maps.smartsantander.eu/ providing this type of visualization of the whole city:

Image 9. Deployment of Devices throughout the City

Source: Author's elaboration based on http://maps.smartsantander.eu/.

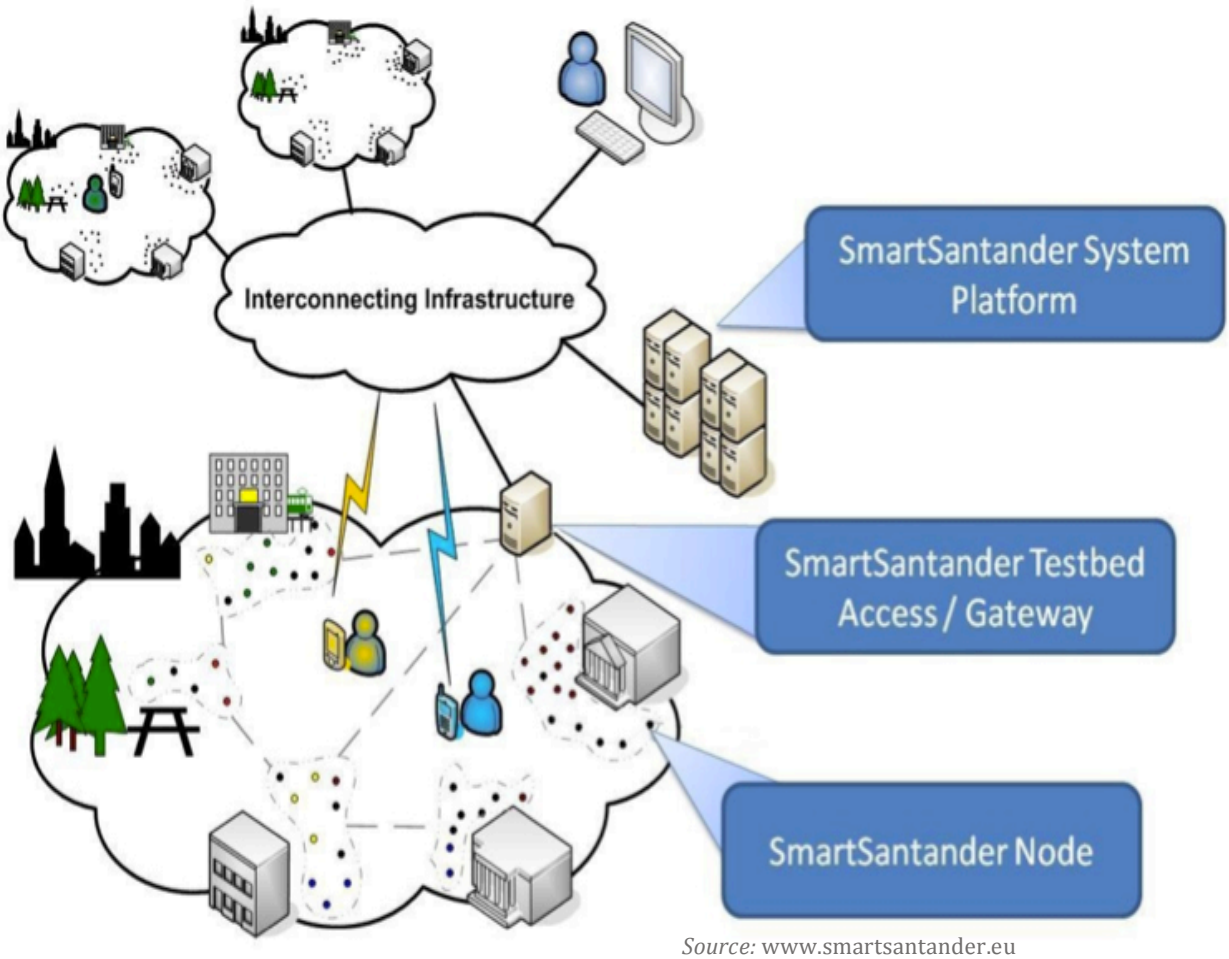
3.3 System Architecture

The description of the system architecture includes information that combines aspects of current systems with details of the system that is about to be contracted and will constitute, with both an integrated and an integrating focus, Santander's Smart City Platform.

To differentiate the information (current vs. future), the letters C for current and F for future will be added to the corresponding sections.

3.3.1 Disposition and General

Figure 3. Systems Architecture of SmartSantander



Source: www.smartsantander.eu

Scheme of the System (C + F)

Until now, the general system architecture corresponded to the SmartSantander Project's architecture. It is depicted graphically in Figure 3. Santander's Smart City Platform architecture, which is about to come online, comprises the following elements and components. Descriptions of these components are found in the list of specific technical conditions that must be met in the open process to contract IT services for Santander's Smart City Platform in service mode and the startup of the Technical Office of the Project (Annex C).[18]

Integration layer and interoperability: Integration is a "component of the solution that must cover the needs of the IoT and that affects the city, permitting the capture, compilation, and real-time analysis of data from devices with interconnection capacity. This component is necessary for interaction with real-time elements of information and action that enable efficient management of the urban services in an integrated fashion" (Annex C).

[18] All citations are from the List of Technical Conditions for Contracting the Services of Santander's Smart City Platform.

- As for interoperability, "[t]he use of the application interoperability component aims to interact with the various sources of data coming from the urban services information systems, both origin and destination, as well as facilitating the creation and maintenance of the processes of extraction, transformation, and loading required for obtaining the information necessary for other components of the solution" (Annex C).
- **Layer for treatment, management, and exploitation of data:** "Component of the solution that permits integration and treatment of large volumes of heterogeneous information from distinct sources that can be identified in the context of cities. The solution will therefore provide an integrated management system that makes it possible to work with a large number of variables and data from diverse sources in real-time conditions, obtaining service indicators with high value added for the integrated management of the city of Santander" (Annex C).
- **Business support layer:** "This layer will be responsible for generating the reports and visualizations necessary for the correct transfer of information to final users and managers, including not only tabulated information, but also graphs, maps and visualizations adapted to the context of usage" (Annex C).
- **Application and access layer:** "The capacity to convert the Smart City Platform into an open platform, both from the viewpoint of entrepreneurs who wish to interact with the platform, and from the viewpoint of the city's service providers" (Annex C).
- **Management layer:** in reference to user management "The solution must provide tools for provision and configuration of the distinct profiles for accessing services provided by the solution itself." As for security, "[t]he solution must be able to integrate with the standard LDAP user management security of Santander City Council. It must have an easy-access (via web), centralized module to be able to do user administration tasks (assignation of permissions, etc.); therefore, it must guarantee security according to the Santander City Council requirements that will be communicated to the entity hired at the beginning of the project" (Annex C).

As can be seen in the description of the five layers that will make up Santander's smart city platform, the system integrates all of the knowledge, software, hardware, and personnel necessary to generate, transmit, treat, and present the data produced in the city.

3.3.2 Technical Information about Data Generation and Treatment (C)

Data and information are generated today thanks to devices deployed by the providers of urban services, by municipal services (municipal personnel), and those deployed thanks to research and management projects promoted by the Santander City Council and the University of Cantabria.

In the case of the SmartSantander project, the sensors installed generate data that, without prior validation processing, are stored in the single repository, the Fi-Ware platform, for exploitation in diverse applications. Among them (for example, those that detect luminosity or noise), those installed on lampposts and facades (connected to the electricity network for power supply) have two radio modules for data transmission: one for the service and another for experimentation. The service is produced through distinct apps,

principally SmartSantanderRA and The City Pulse. Both are available on the principal Android and Apple download platforms.

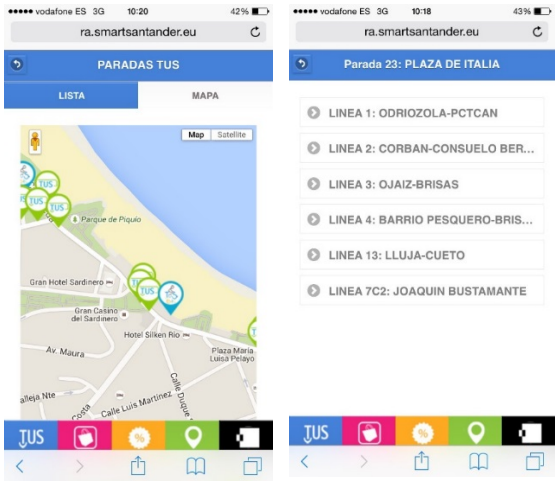
Experimentation and research permit the development of new utilities for the citizens and for the City Council thanks to the collaboration with the University of Cantabria and its Department of Communications Engineering. This collaboration also enables the participation in new research and development projects and the consolidation of the public–private model of collaboration.

In addition to these data associated with the developments within SmartSantander, many more data are generated associated with a multitude of services provided in the city. Each service has its own system for generation, transmission, storage, and treatment of data. Some examples:

Taxis*:* have their own system for visualization and optimization of services thanks to the GPSs installed.

Santander Urban Transport, or TUS*:* has GPS installed in the vehicles (public buses), which enables geo-positioning of the buses and feeding this information back into the system. The Urban Bus Control Center uses this information for decision making.

Image 12. Examples of Visualization of the SmartSantander RA Application



On-street parking*:* the data are generated by ferromagnetic sensors and transmitted until being stored, without validation, in the Fi-Ware platform. It makes real-time information available through the SmartSantanderRA application.

Underground parking*:* information about free parking spaces in each car park is available on the corresponding apps and on the luminous panels sited at distinct points of the city.

TUSBIC*:* JCDecaux operates the municipal bicycle hire service. The information about bicycle availability at each station is available in real-time in the corresponding apps. The company itself does the data storage, although it collaborates with the University of Cantabria for processing and subsequent decision making.

The City Pulse*:* with this app, citizens generate data about an incident using their smartphones. The INCISIS system, which receives the data, generates a warning in the corresponding department and service responsible for resolution of the incident.

3.4 Integrated Operations and Control Center (F)

The Integrated Operations and Control Center or the closest thing that Santander has foreseen, is the Santander Smart City Platform. Its creation is being processed through the list of specific technical conditions that govern the open procedure for contracting the information technology services of Santander's Smart City Platform in service mode and the startup of the project's Technical Office (Annex C). The budget for this platform and its technical office, for a period of four years, is €2,238,660.

The name of the contract itself provides some clues about the integrated center model that Santander is seeking to have. First, the information services will be contracted to integrate the different infrastructures for

capture, transmission, and management of the data from the different urban services, and to assess the development of these infrastructures in the successive services to be contracted.

According to the contract, and in reference to its aim, the result of the knowledge, techniques, programs, and equipment supplied by the service provider will allow the capture and management of heterogeneous information coming from the various services and will make available advanced services, both for public information and for management of the decision-making process. The technical office must carry out the strategic, technical-technological, and administrative tasks necessary for the proper development and operation of the platform.

The 14 services whose integration into the platform is considered a priority in the contract and which constitute the nucleus of the project are:

- Waste management
- Fire service and emergencies
- Integrated water cycle
- Urban transportation service
- Public illumination
- Traffic/traffic light management
- Parks and gardens
- Social services
- Coordination of public road work
- Employment service
- Central technical services
- Human resources
- Local police
- Parking management

For its complete integration, first the indicators or KPIs established for each service in Santander's Smart City Strategic Plan must be taken into account. Then, a command structure must be defined for each service, as indicated in the platform's list of technical conditions. Finally, the city's command structure, in which all the services will be integrated and will interact, will be defined. Physically, the technical services for the correct functioning of the platform will be situated in a municipal building. The data will be stored and treated in the cloud (remote storage, eliminating the need for physical servers in that building). There are still no details on the connectivity infrastructure in this place, given that this depends to great extent on the technical offers made by each business in the tender for Santander's Smart City Platform.

3.5 Field Devices (C)

The variety of field devices installed is shown in Tables 1–3 which logically correspond to the previously explained device classification (static, dynamic, and participatory).

Table 1. General Classification of the Types of Static Devices Installed

Type	Service	Type of sensors
Static	**Environmental**	• Temperature • Temperature + CO • Luminosity + temperature • Noise
	Parks and gardens	• Humidity and ambient temperature • Humidity and ground temperature (for automatic watering) • Wind velocity and direction, precipitation, temperature, humidity, and pressure
	Traffic	• Parking (presence or not of vehicle in a parking place) • Traffic density (number of vehicles in the last minute, percent of occupation of each lane, average and median velocity
	Public security and traffic control	• Closed circuit cameras in tunnels and municipal areas • Cameras for exterior traffic control • IP Cameras with wireless connection
	Water management	• Remote reading modules for billing of consumption • Water quality sensors (Ph and turbidity) • Pressure sensors (basic criterion in the management of this service)
	Trash collection	• Container level sensors
	TUSBIC (public bicycle hire system)	• Presence or absence of units at each hire point

Source: Author's elaboration.

Table 2. General Classification of the Dynamic Devices Installed

Type	Service	Type of sensors
Dynamic	**TUS (public buses)**	• GPS for real-time positioning, waiting time, and distance • Environmental sensors of CO, NO2, O3, temperature, humidity, and particles • Odometer (distances travelled)
	Taxis	• GPS (free taxis at each rank) • Environmental sensors of CO, particles and humidity • Odometer
	Trash collection and street cleaning	• GPS • Environmental sensors of CO, NO2, O3, temperature, humidity, and particles • Odometer
	Parks and gardens	• GPS • Environmental sensors of CO, NO2, O3, temperature, humidity, and particles • Odometer

Source: Author's elaboration.

Table 3. General Classification of the Participatory Devices Installed

Type	Service	Type of sensors
Participatory	**App "The City Pulse"**	Each event reported by a citizen[19] contains the following data: • Title • Type • Description of incident • Image • Day of creation of the incident • Day of final resolution of the incident • Position
	SmartSantanderRA (Augmented Reality)	The citizen's smartphone interacts by consulting and generating information about: • Points of interest in the city (more than 3,000) • TUSBIC (municipal bicycle system) • Taxis • Underground car parks • Cultural agenda (Santander Aúna) • Urban buses • Commerce (timetables, products, offers, etc.) • Open data • SmartSantander sensors

Source: Author's elaboration.

[19] See example of a screen with incidents in Section 2.6 of this document. The most common incidents are: damage on streets, pavements and paths, urban furniture, or traffic http://www.elpulsodelaciudad.com/.

Other devices included in the three previous tables are the QR codes and the NFC tags deployed throughout the city to access services and applications. To date, these have been installed at bus stops to provide information about the different lines and services, and in some businesses to provide information about hours of operation and sales. These will gradually be installed at various points of interest in the city.

3.6 Communication Systems (A)

The communication systems utilized in Santander in relation to the Smart City Project are heterogeneous, as are the devices and the data management systems installed. The main reasons are:

- Evolution of the project. As it was a pioneering project, begun when there was no reference experience, there has been a continuous incorporation of services through research projects and the inclusion of IoT criteria.
- Diversity of agents. The principal agents involved in the development of the Santander Smart City Program are the Santander City Council, the University of Cantabria, and private companies. Each of them develops projects and services in conjunction with the others but also promotes its own initiatives in this field.

Without a doubt, the startup of Santander's Smart City Platform solved the problems derived from this heterogeneity. To date, the information about communication systems can be divided into:

A. Urban Services

Most of the sensors installed to date by the businesses operating some of the services, such as water supply, use proprietary protocols. This means that only the manufacturer or proprietor knows how they operate and that applications cannot be developed without their permission.

In contrast, there are examples of services, such as trash collection, that use the ZIGBEE system, which operates at a wireless frequency of 2.4 GHz and which works under the IEEE 802.15.4 standard.

In the future, Santander's Smart City Platform must provide interfaces for sending data generated from and toward the devices or hardware and software systems of Santander's urban services through any access technology, wired or wireless, based on the TCP/UDP/IP protocol stack.

B. SmartSantander

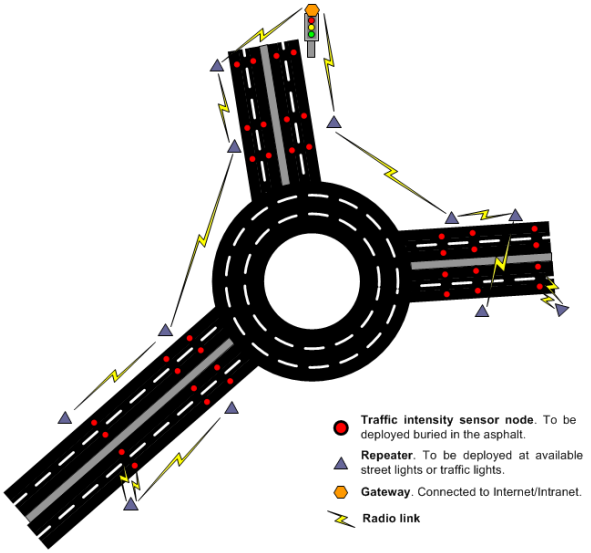
The wireless sensors utilized in the SmartSantander project and its subsequent extensions use the Digimesh system, at the wireless frequency of 2.4 GHz.

The mobile sensors utilize the General Packet Radio Service (GPRS) system or the general service of packets via radio. This system enables data transmission through packaging.

The inputs or gateways (around 25 for the SmartSantander Project system) receive packets of data that are in turn sent for storage in the Fi-Ware platform. Before storing, these data are validated, so it is common for errors to occur, such as the incorporation of out-of-range data. The communication systems utilize 3G gateways and Ethernet.

Next, illustrations of the communication systems of two of the services integrated into SmartSantander are provided: traffic density monitoring and environmental data (mobile sensors).

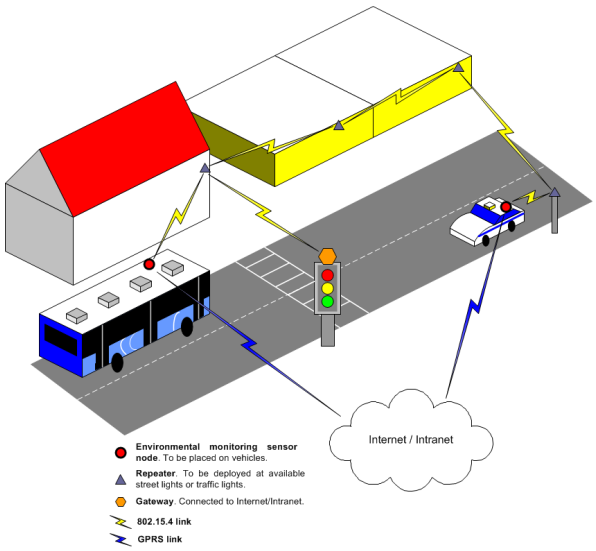
Image 13. Communications of the Traffic Density Control System



Source: www.smartsantander.eu.

The figure above shows the interaction of three types of device in the traffic density control system: inductive sensors or traffic density sensors (they detect passing metallic elements thanks to magnetism), repeaters, situated on lampposts, and links or gateways. The first (sensors), communicate by radio with the second and they are supplied by small batteries. The repeaters enable the signal from the sensors to reach the links, also by radio, from where they are sent on to the data storage platform.

Image 14. Communications Scheme of the Mobile Environmental Sensor System



Source: www.smartsantander.eu.

The scheme of the figure above entitled "Environmental Data. Mobile Devices" is similar to the previous one, although with the difference that the sensors are installed on public service vehicles, such as municipal buses, taxis, and urban trash collection trucks, and are therefore mobile. In this case, the sensors installed communicate via radio with the repeaters situated throughout the city as they pass by them; from there to the links, also by radio, and finally to the data storage platform, normally via Ethernet connection.

3.7 Subsystems and Functions (C)

All of the subsystems have been described in different sections of this document. The data and information from most of them can be consulted directly through the SmartSantanderRA app and the website http://maps.smartsantander.eu/.

Transport and Mobility

The transport and mobility subsystem is one of the most developed and most frequently utilized. It makes available data and information about the municipal bicycle hire system (TUSBIC), information about free taxis, free underground parking places and on-street ones, information about the TUS, and information about the state of traffic flow on the city's roads.

Public Safety

There are cameras placed on buildings and in public areas such as the city's streets and tunnels. The municipal police in its control center manage this information.

It is possible to connect, through the Santander City Council website, to a small number of them. The rest of the information is confidential.

Emergencies

Work is currently being done to incorporate the fire and local police services into Santander's Smart City Platform. However, there is currently no tool that enables the public to access functions in this subsystem.

Environment

The visualization tools available for accessing the city's environmental information provide real-time knowledge such as information about temperature, humidity, solar radiation, precipitation, wind, air quality, noise, ground humidity, and atmospheric pressure. This subsystem is fed with the data that are generated by the more than 20,000 devices installed in the city.

Energy Efficiency

This subsystem does not yet exist as such. Devices have been installed for pilot projects for adaptive illumination, enabling important savings by lowering and raising the light intensity depending on whether or not people are present.

The list of technical conditions has just been published for the street illumination contract (nearly 23,000 lighting points). It includes the obligation to adapt to the needs of the smart system and the integration into the city's platform.

Interaction with the Citizen

The application The City Pulse has opened up the possibility for citizens to be not only recipients but also generators of useful information, by reporting incidents. This application is connected to the incident notification and management system, INCISIS, so that incidents arrive directly via email to the corresponding municipal service.

3.8 Generation of Knowledge (C and F)

In the context of smart cities, the generation of knowledge and intelligence is usually understood in relation to the value added that is generated for the management of a city when data from municipal services are interrelated. In this sense, the amount of intelligence generated by the Santander project until now has basically been acquired through the development of pilot projects and applications and participation in European projects.

The startup of Santander's Smart City Platform will lead to an explosion in the capacity to generate knowledge and intelligence in the urban system. Moreover, it will permit new approaches to the uses of the platform. As a platform for the development of the IoT, implanted throughout the city, Santander's infrastructure will permit services to be provided not only to citizens but also to the academic community, which can experiment with architecture, protocols, and applications.

As a university city that has some of the specialties most closely related to the Smart City Project, and with a scientific and technological park housing a large number of businesses in the innovation and communications sector, there are many very positive factors for generating knowledge and intelligence, exploiting the data and information generated, and for leading Santander in the field.

All of this is favored to a great extent by the duality in the deployment associated with SmartSantander, which foresees both service delivery for citizens and managers and the possibility to experiment. For this, many of the devices installed have two radio modules, one for services and another for experimentation. For the purpose of experimentation, all of the data obtained are stored on the FI-Ware platform.

In relation to the generation of knowledge in the SmartSantander project context, the two open calls for experimentation and innovation projects should be highlighted. The first had a budget of €200,000 and received 47 proposals,

50 percent of which were from industry and oriented to service delivery. The second call had a budget of more than €700,000 and received 31 proposals from six countries.

4. Organizational Structure

Given the current situation of transition of Santander's Smart City Project from an independent service structure without interconnection, to a structure unified through Santander's Smart City Platform, the organization of both scenarios will be described.

4.1 Governance

With regard to governance in the exclusive context of Santander's Smart City Project and the integration of technologies into the lives of citizens, some clarifications should be made:

- Typically, in projects in which the Santander City Council participates, the decision is made by the City Council itself and not by any of its departments. It was the mayor's office that decided on the participation of one or another department, in the case of those related to the Director General of Innovation's Smart Project. It depends directly on the mayor (not to any individual council member) with an annual budget of €5.5 million, including the staff and City Hall's information service.
- As a point of reference, Santander City Hall has divided municipal management into 12 departments:
    - Infrastructure, urban planning and housing
    - Environment, sustainable mobility and technical services
    - Personal autonomy
    - Neighborhoods, public participation, social promotion, immigration, cooperation with development and general services
    - Culture, education and youth
    - Sports
    - Family and social services
    - Personnel and civil protection
    - Tourism and institutional relations
    - Commerce and markets
    - Economy, tax, contracts, heritage, transparency
    - Employment, business development and technical services
- In the case of SmartSantander and in the other 15 innovation projects in which the city participates, the relationship among the partners of the project is formalized through guarantee and association documents for each specific project. In each project, there is usually a leader, who normally receives the funds from the European Union and who allocates to each partner (by transfer) a budget for the development of the assigned tasks in the approved project. In the case of SmartSantander, Telefónica I+D took this role.
- There are various participants involved in the Smart City Project, and distinct initiatives for coordination and relating with them. In the case of the citizens, various means have been used to include them in the project. The most relevant ones are courses (information technology, Internet, and new technologies) at various levels, which are provided for the public in the municipal civic centers, and visits to the SmartSantander Demonstration Center, operating thanks to an agreement between Telefónica and the Santander City Council (the former provides the personnel and contents and the latter, the space where it is installed). Moreover, through apps and websites, citizens can make their

contributions publicly or anonymously, and through the associations (mainly neighborhood associations) they participate in consultation bodies.

- Businesses participate through sectoral innovation meetings held at least once or twice a year, and through active participation in R&D projects as partners. The externalized municipal service providers intervene by integrating the technologies requested in the lists of technical conditions, which since 2013 clearly tend toward their integration in the smart model of the city.

In conclusion, governance of this project is a two-way street. The citizen, the necessary focus of attention of the Smart City model, can be both a beneficiary of the information generated and a generator of information and ideas that guide the evolution of the project (by answering questions such as "what are my needs?" or "what do I expect from my city's smart model?").

4.2 Human Resources

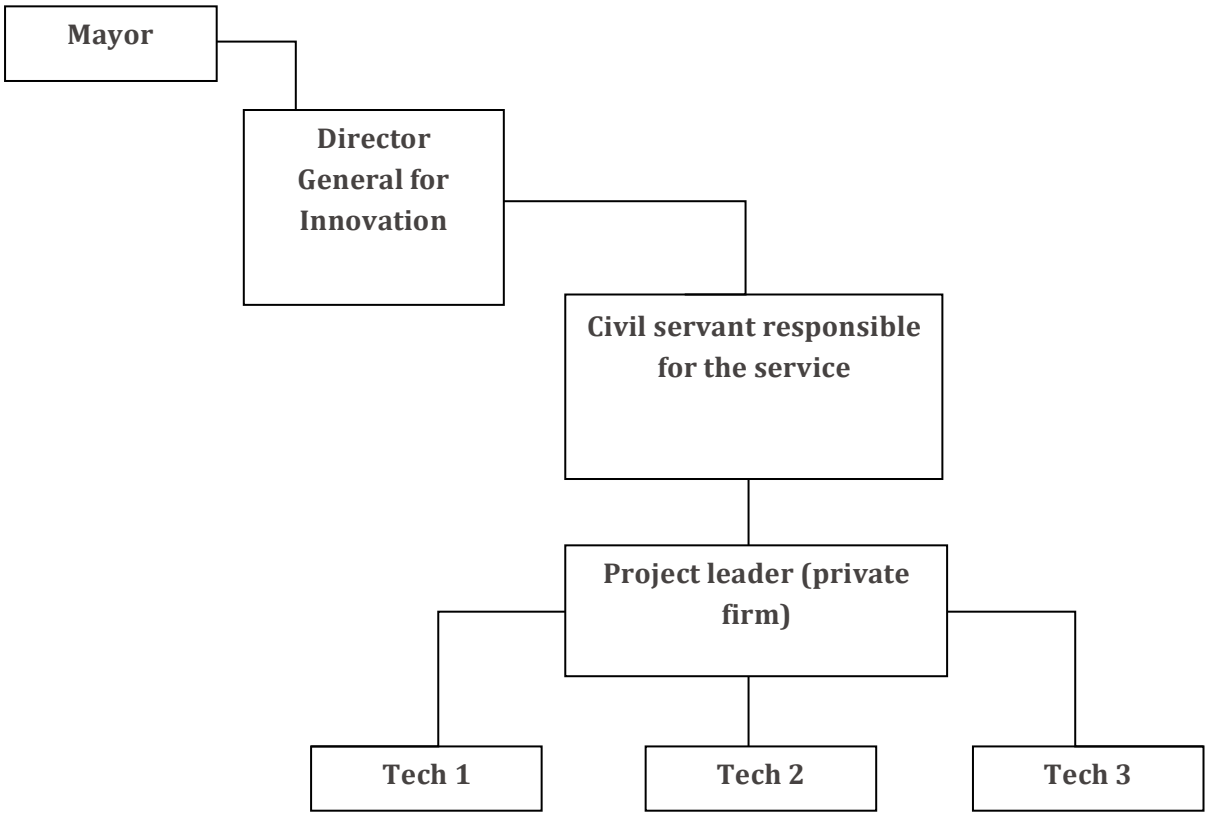
This section distinguishes between the current situation and the future once Santander's Smart City Platform is operational.

Currently, the nucleus of personnel associated with the Santander project is in the City Council's General Directorate for Innovation, with the University of Cantabria providing support for innovation and formulation of European and international projects. The General Directorate for Innovation has a staff of 16 people in the Information Technology and Communications Unit. They include systems programmers, systems managers, heads of service, and administrative personnel (http://portal.ayto-santander.es/portal/page/portal/inet_santander/%5Bhtdocs%5D/pdf_contenidos_diversos/RPT_2013.pdf). Of these, approximately four are specifically assigned to the SmartSantander project.

In the university, the people directly involved, although not exclusively, are in the Telematics Engineering Group directed by Professor Luis Muñoz, the Transport Systems Research Group, directed by Professor Ángel Ibeas, and, more recently, the Urban Planning and Sustainable Management Group directed by Professor José Luis Gil. These three groups have a total staff of more than 45 people, although only a few of them are directly related to Santander's Smart City Project full time. The others work on related research projects but do not provide direct benefits to the city of Santander. For example, during the development of the SmartSantander project, the root of the experience, there were five people devoted exclusively to the project in the Telematics Engineering Group.

Businesses have different situations with respect to human resources. Some, such as the trash collection service provider (the UTE ASCAN-GEASER), have had to add personnel specialized in telecommunication to their staff to be able to meet the demands of the contract in terms of integrating IoT technologies. In this case, it also had to hire third-party businesses to meet those demands. Others, such as FCC Aqualia or Ferrovial, have opted to establish collaborative agreements with the University of Cantabria for research and consultation.

Figure 4. Organization of the Personnel Associated with the SmartSantander Project



In December 2015, some changes were introduced with respect to the aforementioned arrangements. It was necessary to introduce four people foreseen in the list of conditions for contracting the project's technical office, and in City Hall, the tasks and structure of the personnel in this department will need to be consolidated so that they can follow up on contract fulfillment and direct the necessary work.

4.3 Control of the Information, Ownership, and Exchange among Distinct Services

To go deeper into this aspect, it is useful to differentiate between information and data. Data are the raw material of management. They can be generated in different ways, but in this case, and in relation to Santander's Smart City model, sensors generate most of those of interest. These sensors can be static, dynamic, or participatory.

In the current scheme, the people in charge of each service, whether the businesses that provide services or the City Council, receive these data, which they use to generate information for management and to generate knowledge.

In the case of businesses that provide services, it is customary to receive data and write reports to hand in to the corresponding department. Their periodicity is variable, from daily to annual reports. In the new model, which will be implemented in the next few months, all of the data and the information generated will be concentrated in a single control center, which will enable greater control and better performance by the City Council.

The Santander City Council owns the data, although in some cases, service providers have no obligation to cede their data or must only do so for specific uses, such as the feeding of information from apps. This is true of taxis or the city's underground car parks, which cede the information in order to update the various applications. Today, for example, all of the information generated is stored on the Fi-Ware platform (https://www.fiware.org/), where

the users of Filab, an ecosystem for the experimentation of entrepreneurs and persons,[20] can make use of it to develop new services and applications.

In 2016, all of the information generated will be sent to the city's platform, and the City Council will determine the access profiles, the potential uses, and the availability of the data on the city's open data space.

4.4 Budget and Cost of the System

For this section, only information about the city's future Smart City Platform can be provided since, in the current scheme. the costs are distributed among many concepts and departments.

Without counting the whole infrastructure that is already installed (some €90,000 per year in maintenance and guarantees for the devices of the SmartSantander project), and the future devices to be integrated through successive contracts for the provision of public services, the main costs of the functioning of the city's platform for the four-year period are indicated in Table 4.

Table 4. Main Costs of the Functioning of the City's Platform

Provision 1. Santander Smart City Platform Software.	**€189,728 annually (VAT included) Contract Total: €758,912 €**
Provision 2. Technical office and maintenance of Santander Smart City Platform software.	**€369,937annually (VAT included) Contract Total: €1,479,748**
Contract TOTAL, with VAT and for 4 years	**€2,238,660**

[20] https://www.fiware.org/lab/.

4.5 Other Useful Information

The role of public–private collaboration in the development of Santander's smart city experience is very important. A brief account of these collaborations could be very useful.

- Agreement between the Santander City Council and Telefónica for the development of the Municipal Master Plan for Innovation and the startup of the Santander Smart City and Entrepreneurship Demonstration.
- Agreement among Santander City Council, FERROVIAL, and the University of Cantabria for the creation and operation of the Center for Research on Smart Cities, or CICIS.
- Agreement between the Santander City Council and the technological firm, NEC, for the development of a first model of a city "brain" that enables the control of urban services to be integrated.
- Agreement among the Santander City Council, the Santander Bank, ISBAN, and the firm IBM, for the creation of the Santander City Brain website, which enables citizens to make proposals for city management.
- Agreement among the Santander City Council, the regional government of Cantabria, and the Santander Bank for the implementation of contactless payment in infrastructure and transport systems, commerce, and tourism.
- Agreement between the Santander City Council and Microsoft for access to good practices in the sector and for the provision of technological tools for local entrepreneurs.

For all of the agreements cited, the department in charge of management on behalf of the City Council was the General Directorate for Innovation. It has contributed to the

development of an appropriate legal framework for these types of projects, collaborating with the Municipal Financial Team, and it is proving essential given the difficulties of introducing novelties into traditional service contracts. Obviously, introducing ICTs into services such as urban solid waste collection is considered by legal and financial services to be a novelty.

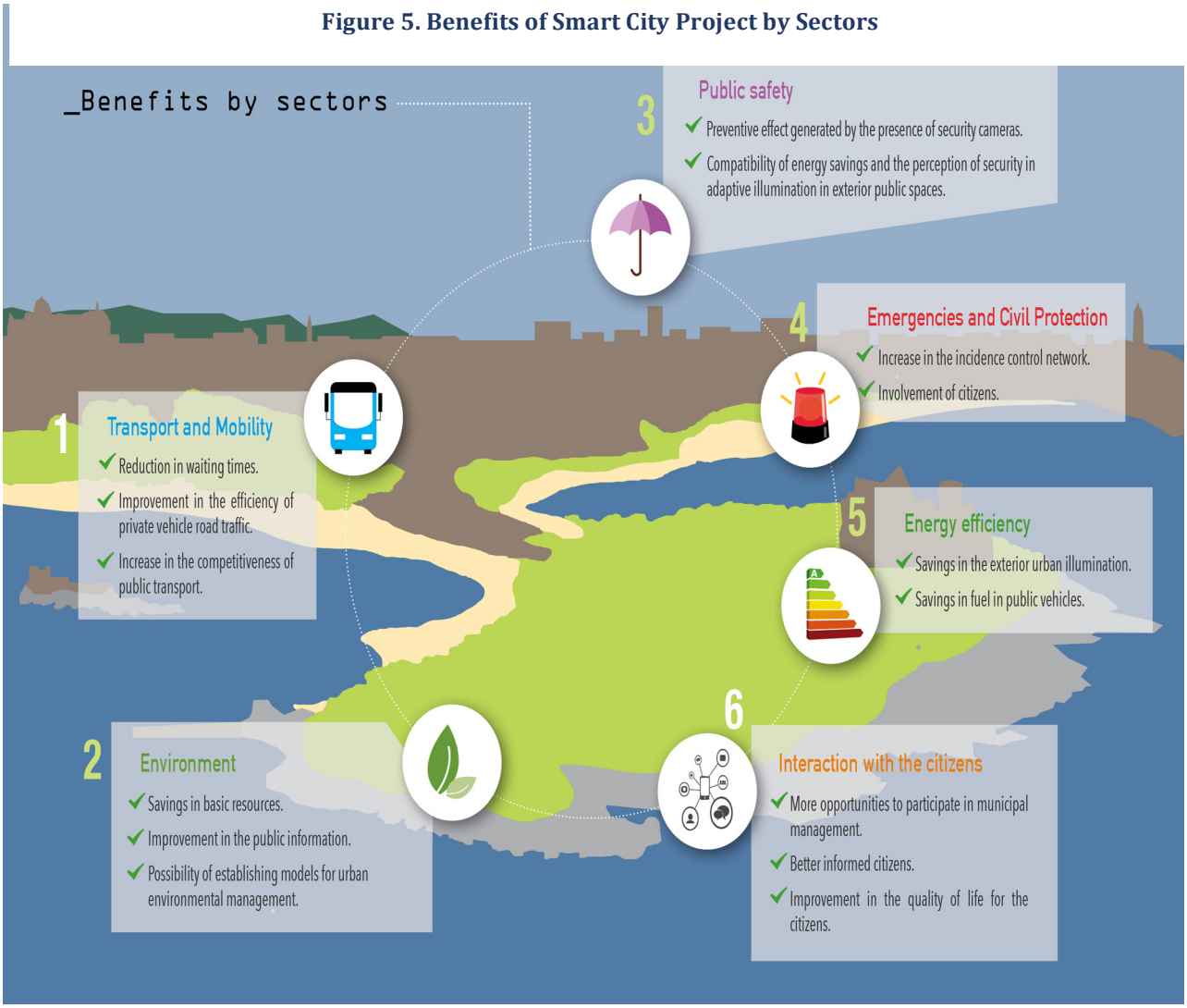
5. Monitoring and Control

As has been verified throughout this Santander case study, there is a high degree of monitoring in most basic urban services. The current challenge lies in changing from many well monitored services with no exchange of information among them to a single platform integrating all of the services and generating intelligence with their interrelation.

5.1 Benefits by Sectors

Most benefits provided by the development of Santander's Smart City Project have until now been aimed at improving information and the quality of people's lives. Following the system structure proposed by the management of the works in relation to the case study, the principal benefits are included in Figure 5.

Figure 5. Benefits of Smart City Project by Sectors



5.2 Quantitative and Qualitative Evaluation Methods of Benefits

The recently prepared Smart City Strategic Plan establishes a series of KPIs or indicators for the city and the evaluation of each system installed in the city based both on the Santander Strategic Plan and the ISO 37120 norm (measurement of the development of cities).

Table 5. Indicators of the Smart City Strategic Plan

Strategic axis	Strategic objective	Total number of indicators	Examples of proposed indicators
Governance, economy, and employment	Santander City Lab	43	• Number of patents per 1000 habitants per year. • Number of firms dedicated to R&D&L
	Smart management of public services.	3	• Debt compared to income. • Fixed assets compared to total consolidated expenses.
	Open and participative Government.	37	• Number of associations. • Municipal investment in participative budget.
Sustainable development and infrastructures	Smart Management of Urban Infrastructures.	65	• Percentage of homes with access to NICT. • Number of public services available on line.
	Urban Sustainability.	74	• Tones of solid urban refuse collected per inhabitant per year. • Liters of water consumed per inhabitant per day.
	Energy Efficiency.	15	• Photovoltaic potential installed per 10.000 inhabitants. • Consumption of electricity in public illumination.
Quality of life	Smart destination.	32	• Number of tourist per 1000 inhabitants. • Daily expenditure of tourists.
	Citizen focused orientation of services	53	• Municipal expenditure on social policy. • Response time of the emergency services.

Source: http://portal.ayto-santander.es/portal/page/portal/inet_santander/%5Bhtdocs%5D/pdf_contenidos_diversos/2.%20Pl

Specifically, Santander's Smart City Strategic Plan establishes 322 indicators structured in three strategic axes: governance, economy, and employment, sustainable development and infrastructure, and quality of life. Table 4 summarizes these indicators.

To date, a quantitative evaluation has been conducted on aspects such as water consumption for watering the parks and gardens (specifically, the savings from the implantation of humidity sensors), energy consumption by public illumination (savings effect of the presence of sensors and adaptive illumination at night), and the operating cost of certain services (reduction in fuel costs, and the possibility of avoiding physical displacements to solve problems). In any case, since many of these aspects have been tested through pilot projects, their benefits have still not been scaled up to the whole city (although they are gradually being introduced in the ICTs in different contracts thanks to the knowledge obtained), nor have estimations of savings been published. Qualitatively, the benefits are evaluated through the assessment of the services by the users (polls or intensity of use of the available tools).

5.3 Degree of Integration and Synergies

From the standpoint of crosscutting urban management, the Santander experience has still not been integrated to a great extent. The startup of Santander's Smart City Platform will enable this deficiency to be addressed; the solution is the product of more than five years of experience as a smart city.

The only contract already awarded in which ICT use is integrated into the provision of the service is urban trash collection. The road cleaning contract foresees some aspects, such as:

- Hardware, software, and integration necessary for the development of the work under the list of conditions described in the contract.
- Installation, cost, configuration, and maintenance of the communication lines necessary for integrating this service into the City Council's remote systems.
- The IT equipment (hardware and software) acquired for developing the work must be homogeneous with the equipment available at City Hall so that total compatibility among them is guaranteed.
- The winner of the contract accepts the task of data capture, ensuring interoperability with the other city systems as well as the exchange of data and information.
- In addition, the contract winner must assume the costs of connection and utilization of the data repository necessary to fulfill the objectives of the contract, estimated to be a maximum of €150,000 per year.

One of the most illustrative synergies in the possibilities provided by a smart city is the combination of urban noise monitoring, management of emergencies, and traffic light control. The EAR-IT project incorporates the possibility of detecting emergency vehicle sounds (fire service, police, and ambulances) through the sensors installed and to modify the traffic light control sequence to facilitate the passage of these vehicles to their destination.

5.4 Expectations and Interested Parties

Based on the interviews and the information compiled during the documentation and

analysis phase, the principal expectations of the various agents are:[21]

Santander City Council

The City Council expects to fully integrate ICTs into all public services where possible and to integrate all of these services into a single command module of the city, which will improve services and people's quality of life. It will also lower costs and increase efficiency in the delivery of services.

Derived from the previous point, the Santander City Council wishes to continue being an international referent for smart cities, promoting the creation of new knowledge-intensive companies, the consolidation of existing ones, and their positive impact on employment of highly qualified staff and competitiveness of the city and its citizens.

Local Technological Companies or Those Installed in the City

These types of companies have two expectations. One is to raise the prestige of Santander in this area, in order to improve the positioning of its companies in national and international markets. The innovative environment of the Smart City project can provide an imprimatur of quality.

Their other expectation is that the city and the experimentation and data exploitation possibilities enable improvements in their products and services and the development of other new ones.

Urban Service-Provider Companies

These types of firms seek to achieve three objectives:

- A reduction in the service operating costs through the incorporation of ICTs, which will in many cases require an initial investment unrelated to the habitual activity.
- Greater competitiveness and more possibilities to win tenders in other cities due to the positive impact of integrating ICTs into the traditional way of providing services.
- Improvement in the quality of service delivery for the user, which will improve the image and user satisfaction thanks to the resources made available to the citizen.

Citizens

- Citizens expect that all of the developments generated by the project will bring about an improvement in their quality of life. They are also interested in maintaining their privacy while using the information that they can generate through their smartphones, a key tool for taking advantage of the available utilities.
- Similarly, they expect more transparency in public administration and increased public participation.
- Finally, and as a logical consequence of the country's current socioeconomic circumstances, citizens expect that the incorporation of ICTs into public services will not result in higher taxes.

6. Lessons Learned

Why Santander?

- The infrastructure, the experience, and the planning carried out in Santander are enabling the transformation of a management model from a reactive city to a proactive one. This should generate savings in the management of public services and permit better adaptation to change (urban resilience).

[21] Point 2 of Annex B –Bibliography.

- The small size of the city (176,000 inhabitants) and the extensive deployment of ICTs make Santander an ideal scale for experimentation and for integrated development of the smart city model.
- The city's strategic planning and the developed smart city model itself have been key elements in the success of the project.
- The universities located in the city have undoubtedly facilitated the development of a true smart city. The generation and practical application of knowledge and research produce a very favorable ecosystem.
- One of the most interesting aspects of the experience is the possibility to manage infrastructure graphically and to have geographically updated and referenced information about the different services. Today, an "unconnected" city is an uncompetitive city.

The relationship with the public

- One of the least developed aspects of this experience is dissemination and the teaching necessary to enable the citizens to understand the transcendence of the city's smart project.
- The goal is not the devices, but the services that they provide to the citizens and the city managers.

The relationship between the public and the private sectors

- Close collaboration between the public and the private sectors is essential to be able to carry out a smart city project successfully.
- The support of the businesses of the sector and the promotion of its implementation in the city are essential. Technological firms that create jobs in the city receive exemptions from payment of 60 percent of their property tax (IBI).

The Evolution

- In Santander's new urban development, integration of ICTs is today considered as basic as the water supply or road systems.
- The leadership of Santander as a smart city is allowing the modification of its vocation as a city, from a city with local and regional services to one that provides global services, thanks to the strategy of innovation.

In addition to the conclusions mentioned above, the following table includes the main conclusions expressed in the interviews with public and private entities that participated in this project.

Table 6. Perceptions of Agents Interviewed

Subjective vision of the agents involved in Santander's Smart City Project	
Strengths	• Starts from a pioneering research and development project (with funds from the EU). • Covers all the strata related to the smart city paradigm, from deployment of technology to improve urban services to the conception of advanced services with the aim of improving the citizens' quality of life. • It is a living laboratory open to the scientific community, industry, and the citizens. • Holistic character, with integration of a variety of participants who have enabled the consolidation of the city's ecosystem. • Cooperation between the City Council and the university. • Having made this smart city project a strategic element of the city.
Weaknesses	• Relative absence of a company in the technological environment linked and/or backing the SmartSantander Project (Some of those interviewed indicated that the ideal smart city is linked to one large company and not to several, as in Santander, to be a one-stop shop). • Limited involvement of the citizens despite the efforts made. • Absence of a clear framework for standardization and regulation that enables the city to reduce costs derived from ICTs in urban services. • Absence of a legal framework in tune with the current conditions and possibilities (The legal framework evolves much more slowly than the technology, and this produces imbalances.).
Desired future	• Existence of a road map with actions and projects to change the city's management model. • Generalized adoption of ICTs in urban services. • Participatory citizens fully involved in the smart city phenomenon, in which they not only "consume" services but also conceive, propose, design, and validate them. • Santander converted into a pole of excellence in relation to the technologies of the IoT and the services supported.
Undesired Future	• Lack of communication with the citizens. • Not being able to achieve an efficient change model. • Having "technified" the city without excessive repercussions for the citizen, except for the simple use of mobile applications. • Inability to attract industries linked to the value chain of the smart city paradigm.

Source: Author's elaboration.

7. Conclusions

Santander's Smart City Project has contributed definitively to increasing competitiveness, which has enables the city to reorient itself toward providing global services. It is obvious that this project is one of the factors that have enabled a small city of 176,000 inhabitants to have a much greater impact and relevance than its size would indicate.

Since 2009 and throughout the process, the collaboration between the City Council, the University of Cantabria, and the private sector has been key to achieving the success of the project. In this sense, the political leadership, the intense research activity, and the investment capacity of the private sector have been decisive. The formulas of public–private collaboration have been and are varied, from public–private consortia for presenting projects for EU funding, to collaborative agreements, or the introduction of research clauses in public contracts (a percentage of the contract must be dedicated to collaboration in R&D with the public university). The City Council wishes to improve its services with smarter projects, but it does not have sufficient economic capacity to do so. Businesses have the economic resources but wish to reduce uncertainties when investing. Public–private collaboration contracts are a good formula due to the lengthy contract periods (the contracts are changing from 5 years to contracts of 10, 15 or 20 years). The university has highly skilled personnel, but does not have sufficient financial resources to retain talent in its R&D groups; this type of collaboration enables their stability and provides an option for generating knowledge.

More than the advanced details of the technology installed, and its function, the direction that this project has taken has been determined by the decision to integrate ICTs into urban services. This can be seen in the contract for the development of Santander's Smart City Platform and in the introduction of related demands in each new contract tendered.

Given that Santander is now in a period of transition toward an integrated city platform enabling a global vision and the generation of intelligence, the great challenge for the city now is to ensure a successful transition. To achieve this, the lessons learned in the last five years will play a fundamental role.

Annex A. Advanced Technical Specifications

1. Integrated Operation and Control Center: Santander's Smart City Platform

The technical specifications of Santander's Smart City Platform are available in the *List of Technical Conditions of the Services Contract* (Annex C.)

2. Field Devices and Communication Systems

The most repeated system, in terms of static devices, is the one shared by the pay and display parking place control, environmental monitoring in parks and gardens, and the management of watering in parks and gardens.

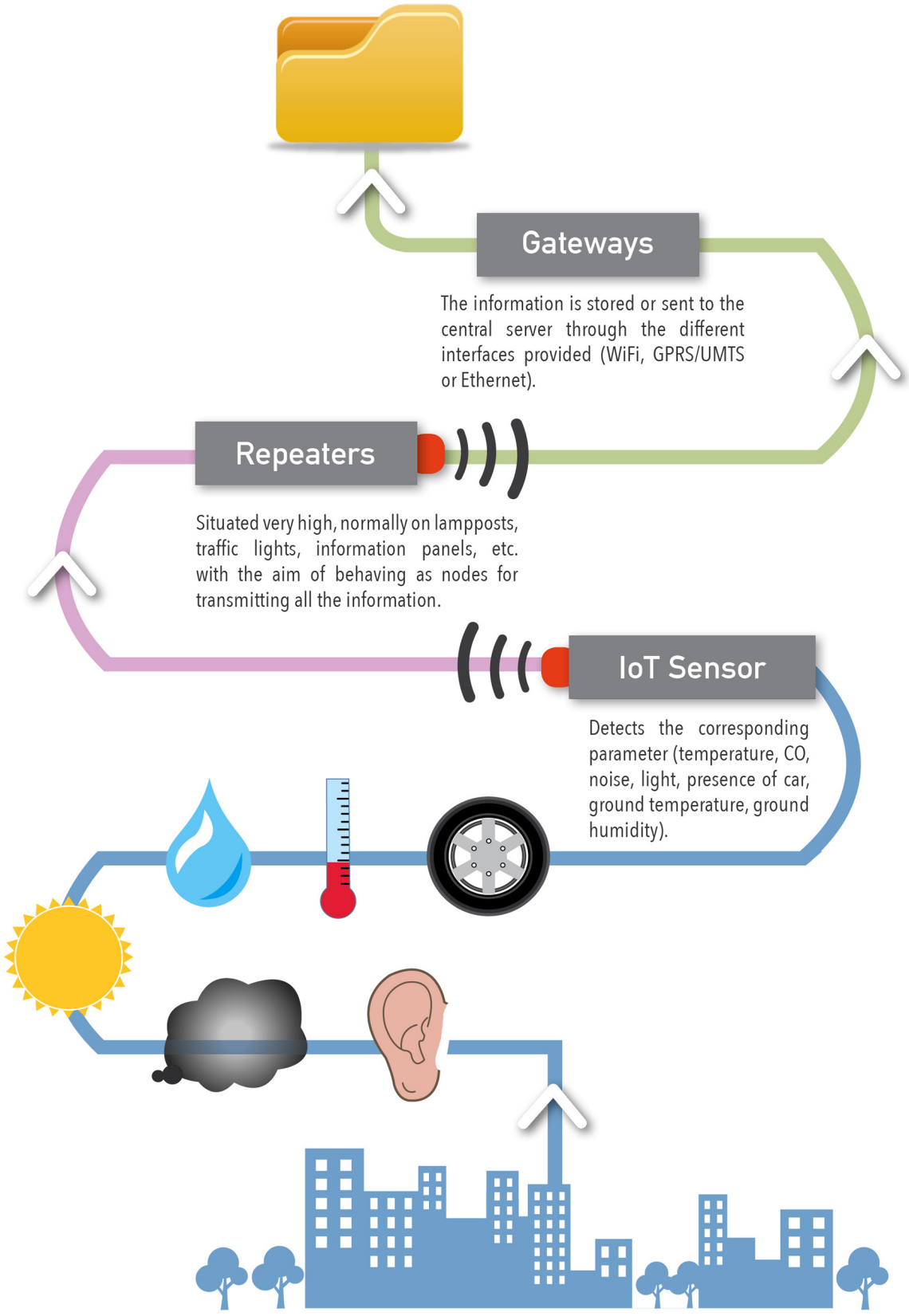
These three usage cases have the same hardware technology for deployment and implementation of specific software architecture, with the aim of managing the service-experimentation duality, as well as managing the networks simultaneously. In this case, the architecture has three tiers:

1. IoT Sensor: detects the corresponding parameter (temperature, CO_2, noise, light, presence of a car, ground temperature, and ground humidity). Most of them are battery-operated, as they cannot be connected by wires to a power source (except those installed on lampposts).

2. Repeaters: these nodes are situated at a great height, normally on lampposts, traffic lights, information panels, and the like. They transmit all of the information associated with the various parameters measured. Communication between repeaters and sensors is done via radio through the 802.15.4 protocol.

3. Gateways: both sensors and repeaters are configured to send all of the information (through the 802.15.4 protocol) for experimentation, service, and connection with the gateways. Once the information is received, it can be either stored in a database on a web server that is directly accessed via Internet or sent to another machine (central server), through the interfaces provided (Wi-Fi, GPRS / UMTS or Ethernet).

Figure A1. Review of Types of Field Devices Installed and Communications Systems



Annex B. References

1. Information Sources

Websites

Santander City Council, available at: http://portal.ayto-santander.es/portal/page/portal/inet_santander

SmartSantander, available at: http://www.smartsantander.eu/?template=retro

SmartSantanderRA: Santander Augmented Reality Application, available at: http://www.smartsantander.eu/index.php/blog/item/174-smartsantanderra-santander-augmented-reality-application?template=retro

Spanish network of Smart Cities, available at: http://www.redciudadesinteligentes.es/

Spanish National Statistical Institute, available at: http://www.ine.es/

Cantabria's Statistics Institute, available at: http://www.icane.es/

University of Cantabria, available at: http://web.unican.es/

Interior Ministry of the Spanish Government, available at: http://www.interior.gob.es/

Esmartcity.es digital magazine, available at: https://www.esmartcity.es/

EAR-iT Project, available at: http://www.ear-it.eu/concept

Documents:

Santander Strategic Plan 2020, available at: http://www.planestrategicosantander.com/

Santander's Smart City Strategic Plan, available: http://portal.ayto-santander.es/portal/page/portal/inet_santander/%5Bhtdocs%5D/pdf_contenidos_diversos/2.%20Plan%20Estrategico_Sant_Smart_City.pdf

Santander City Council Master Plan for Innovation, available at: http://portal.ayto-santander.es/documentos/plan_director_innovacion.pdf

Survey of Information and Communication Technology use in Businesses. Cantabria 2013/2014, available at: http://www.icane.es/c/document_library/get_file?uuid=1202a80f-be6d-479c-b400-8d98174d6268&groupId=10138

Report on Crime Statistics January-March 2015, available at: http://www.interior.gob.es/documents/10180/3066430/informe+balance+2015_ENER_MARZ.pdf/3106219f-7d60-4f01-911e-b4c4cc46fe48

The Information Society in Spain 2014. Telefónica Foundation, available at http://www.fundaciontelefonica.com/arte_cultura/sociedad-de-la-informacion/informe-sociedad-de-la-informacion-en-espana-2014/

Articles:

Galache, J. A. et al. "Towards Experimentation-Service Duality within a Smart City Scenario." presented at Wireless On-demand Network Systems and Services (WONS 2012), Courmayeur, Italy, Jan. 9–11, 2012.

_____. "SmartSantander: A Joint Service Provision Facility and Experimentation-oriented Testbed, within a Smart City Environment." www.smartsantander.eu

_____. "A Living Smart City: Dynamically Changing Nodes Behavior Through Over-the-Air Programming." Presented at Advanced Information Networking and Applications (AINA-2013) Conference in the International Workshop on Pervasive Internet of Things and Smart Cities (PITSaC 2013), Barcelona, Spain, March 25–28, 2013.

2. Agents and Contacts Consulted

José Antonio Teixeira Vitienes. Director General for Innovation at Santander City Council.

Luis Muñoz. Full professor, School of Telecommunications Engineering, University of Cantabria. Telematics Engineering Group.

Verónica Gutiérrez Polidura. Researcher with the Telematics Engineering Group at the University of Cantabria.

Victor Martinez. Head of Smart Solutions with NEC Ibérica.

Pablo de Castro. Conceptual KLT (company dedicated to the generation of new technological projects).

Joaquín González Ruiz. Director of Telefónica in Cantabria.

Annex C. Links for Downloading Information

1. Smart City Strategic Plan (assessment, strategic map, project details, and roadmap http://portal.ayto-santander.es/portal/page/portal/inet_santander/ciudad/smart_city
2. Article "SmartSantander: A Joint Service Provision Facility and Experimentation-oriented Testbed, within a Smart City Environment." http://smartsantander.eu/downloads/Presentations/SmartSantander_A_joint.pdf
3. Article "SmartSantander: The Meeting Point between Future Internet Research and Experimentation and the Smart Cities." http://www.smartsantander.eu/downloads/Presentations/futurenetworksummit2011.pdf
4. Dropbox File: https://www.dropbox.com/sh/iky0iste0vgt2v8/AAC5DIw1PZtL6Lu38vX8eYcua?dl=0

Contents:

- Course file "New Technologies and Public Participation: A New Context for City Management." Brochure and report of conclusions.
- Photo file.
- Article "SmartSantander: a Joint Service Provision Facility and Experimentation-oriented testbed, within a Smart City Environment."
- Survey on the use of ITCs in businesses in Cantabria, 2014.
- Report on criminality, March 2015. Interior Ministry of the Spanish Government.
- Report "The Information Society in Spain" by the Telefónica Foundation.
- Santander City Council's Master Plan for Innovation.
- Santander Strategic Plan 2010–2020.
- List of technical conditions for Santander's solid urban trash collection contract.
- List of technical conditions for contracting the services of Santander's Smart City Platform.

Annex D. Template of the State of Development of the Distinct Services

Range of services		Functions and smart city technologies				
Service domain	Service system	Service system	Compilation of data and monitoring	Service system	Compilation of data and monitoring	Service system
		Signal controller, image detector, BIS, closed circuit television, ...		Smart city operational center	VMS, VDS, BIS, Internet, mobile devices, call center, e-administration, Open-API, radio emission, and communications	Information platform (ownership, control, and follow-up system)
Transport and urban mobility	Adaptive traffic light system	3	3	3	2	3
	Advanced travel systems	2	2	2	3	2
	System of public transport information	4	4	3	3	3
	Incident management system	3	3	3	3	3
	Parking information system	3	3	2	3	2
	Parking with time limitation	2	2	1	2	2
Public safety	System for management of criminality	1	2	1	1	1
Emergencies and protection civil	System for management of disasters	1	1	1	1	1
Environment	System for water management	3	3	3	3	2
	Waste management system	2	2	2	3	2
	Environmental control system (noise, air quality, climate.)	3	3	2	3	2
Energy efficiency	Energy management system	2	2	1	1	1
Interaction with the public and communication means	Systems of communication with the public	3	3	3	3	3

Note: The numbers refer to the different levels of performance according to the following references: 4: Advanced; 3: Moderated; 2: Basic, 1: to be introduced in the future and 0: Absent.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