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Business model analysis of public services operating in the smart city ecosystem: The case of SmartSantander

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Abstract

As the deployment of Internet of Things and other enabling technologies is still in an initial phase worldwide, few research studies have addressed the associated business models. This paper aims to fill this gap. The main objective of this research is to gain a deeper knowledge about practical business models matching into a real-life smart city ecosystem. Hence, a benchmarking of eight urban services provided in the city of Santander has been carried out: waste management; water supply; traffic management; street lighting; augmented reality and tourism; incidences management, parks and gardens and citizen participation. Among the main results of our study, we highlight that those public services properly managed embedding IoT technology convey cost reductions in the long term. There is also a reduction in energy consumption and environmental impact with the consequent social impact. It should also be highlighted that most data are managed with the same platform. Last but not least, an emerging ecosystem of incentivized citizens has been proved to be arising.

Keywords: smart cities; business model; Canvas; sustainability; Santander; IoT;

1. Introduction

Progress in ICT (Information and Communication Technologies) solutions have enabled not only the private sector, but also public institutions to radically improve the way they perform their operational activities [1]. This has inspired particularly local government administrations to transform the way services are offered to citizens [2]. The cities themselves firmly believe that innovative uses of ICT will foster sustainable city innovation that is able to improve the quality of life of its citizens [3].

Smart cities with instrumentation and interconnection of mobile devices and sensors can collect and analyze data gathered and improve the ability to forecast and manage urban flows, thus push city intelligence forward [4].

We identify a smart city as one with a comprehensive commitment to innovation in technology, management and policy [5].

Modern cities are facing a variety of challenges ranging from ecological sustainability or climate-neutral architecture to new socio-economic opportunities, budget cuts or global accessibility. Clearly, improvements in smart governance systems are of paramount relevance for the success of smart city strategies [6]. In addition, the latest technological developments open up different ways of creating value in cities and, thus, new business models.

As the first projects for smart cities are still ongoing [7], different aspects remain vague. Financial sustainability and business models are among the issues pending to be fixed [8–10]. Even though the message that smart cities require new business models [8] is well repeated, few research studies have been published describing such practical business models.

This research is an initial effort towards bridging the existing knowledge gap in the literature. More specifically, the main objective of this research is to acquire a deeper knowledge about practical business models aiming at fulfilling present and future city requirements in the city scenario. In particular, we will be coping with the following four research questions:

RQ1: Do public services implemented with smart technologies in smart cities differ in their business models from those managed as conventionally?

RQ2: Are the economic impact of public services developed with smart technologies higher or lower for citizens related to those managed as traditionally?

RQ3: Are the environmental costs of public services developed with smart technologies different from those managed as conventionally?

RQ4: Does the use of public services developed with smart technologies stimulate different stakeholders' participation in order to achieve sustainable solutions for environmental, social or economic issues?

In order to address these questions, we have examined eight use cases related to urban services and to citizen participation performed in the city of Santander, Spain. We have focused our research on this city due to its innovative projects within the context of smart cities [11–14] and its recognition as a pathfinder in smart cities' technology and management [15,16]. Following the eight case studies, we conducted a double benchmarking: the first one, between the conventional way of managing those municipal services

and the management developed with innovative ICT solutions. The second one highlights the differences among the eight types of public services.

The remaining of the paper is structured as follows: section 2 describes the smart cities and business models concepts. In section 3 we explain the methodology used for the research. Section 4 is dedicated to the results of the case studies analyzed and the benchmarking developed. In section 5 we discuss the results and in the number 6 we report the conclusions, the limitation of our research and propose lines for future work.

2. State of the art

Smart cities are a subject of research that has generated a growing interest in the scientific community during the last decade [17]. The business model is one of the areas considered most important by the changes that the smart city produces in public services [18]. However, the scientific literature that analyzes their business models is reduced because there are currently few smart city projects underway and those that exist are small scale [19]. Precisely, this is one of the reasons that put the value of this article. The following table presents a description of the main published works (Table 1).

Table 1. Research articles published regarding business models in smart cities

Research Topic	Authors and Year
Development of a specific framework for the analysis of business models in smart cities	[20–26]
Prospective discussion of possible business models that will operate in smart cities	[8,17–19,27–33]
Analysis of existing project business models applicable to smart cities	[34–40]

2.1. Concept of smart city

The smart city concept varies dramatically depending on the approach [20]. Making simple the controversy, it can be said that there are two different approaches. On the one hand, the vision of those who understand the concept “smarter” in the urban context as more efficient, sustainable, equitable, and livable [41]. On the other hand, a vision closer to industry that prefers to emphasize that the smart city denotes an instrumented, interconnected, and intelligent city [42]. However, the most significant features

around smart cities can be summarized as follows: 1) The technological innovation; 2) The policy innovation; 3) And the management innovation [43].

Caragliu states that a smart city is characterized by a clever combination of investments in – and a clever use of – resources (in particular, human, social, creative, infrastructural, technological and business capital) that fuel sustainable economic growth and produce a high quality of life, under conditions of a wise management of natural resources and a broadly supported governance system [44].

Six main areas can be identified in which these digital innovations should make a difference: smart living, smart governance, smart economy, smart environment, smart people and smart mobility [45].

The Internet of Things (IoT) is one of the main technologies deployed in smart cities. It consists on interconnecting new services to the physical and virtual worlds through electronic devices distributed in houses, vehicles, streets, buildings and many other public environments. Hence, a massive amount of data will be flowing over the Internet.

Although IoT deployment in smart cities is still in an initial phase [7], various projects using IoT and other emerging technologies have being set up in the European Union [3]. Santander is one of the cities that has gained more attention since in 2009 the SmartSantander project was funded by the European Commission's FP7 [7,46–49].

2.2. Public services in smart cities

e-Government applications enhance cost efficiency and effectiveness in the public sector, and bring about transformational change in public service provision, administration and engagement with the general public [50]. Technology is key for being a smart city because of the use of ICT to transform life and work within a city in significant and fundamental ways [51]. ICT applications can offer some solutions when addressing those political, managerial, democratic or material challenges.

There are many examples of smart solutions in public services to improve the quality of life in cities across the world [28]. A wide range of smart services can be deployed as part of smart city initiatives, including transportation, environment, building, education, tourism, healthcare, public safety – to use real-time information to anticipate and respond rapidly to emergencies [7].

2.3. Business models in smart cities

The term “Business Model” has been documented broadly in business and academic environments during the last few years [52] and various researchers have developed frameworks to analyze business models. In particular, Osterwalder’s Business Model Canvas has gained significant attention within the entrepreneurship mood [53].

A business model describes the rationale of how an organization creates, marketing, delivers and captures value [54]. Nowadays, business model innovation is often more important than a better idea or technology [55].

Smart cities require new business models [8] but there is not only one municipal business model and none is better [34], they depend of different factors, being the character of the stakeholders taking part in the network one of the main ones [35]. Cities are made of subsystems which interact, i.e. an ecosystem [25].

2.4. Smart city ecosystems

Biological ecosystems are systems composed of organic and inorganic matter and natural forces that interact and change [56]. Cities are ecosystems where sustainability is maintained through the interactions of urban components [36].

In the smart city ecosystem, the different stakeholders perform a more active role [57]: private sector participation is key in project sustainability [58,59]; citizens can interact directly to city officials and generate useful data coming from digital footprints, social media and crowd sourcing [48,60]; Governments foster the collaboration of different actors [61]. As the stakeholders of novel ecosystems adopt a different role in the value chain, they are forced to reshape their business models; therefore, smart cities also raise new business models [17]. A large number of real life smart city ecosystems are now being analyzed around the globe; it is the case of the European Network of Living Labs (ENOLL) [62].

3. Methodology

We have chosen the case study method in order to address the four RQs highlighted previously. The case study is a good research strategy for examining a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [63]. A lack of prior theorizing about a topic makes the inductive case study approach an appropriate choice of methodology for developing theory [64]. Using cases to recognize patterns of relationships is appropriate to develop theory inductively [65]. We use the case studies’ results in order to address the RQs and to draw several conclusions.

The case studies chosen for the current research were selected from the smart city's paradigmatic project of the city of Santander. Eight public services, operating in Santander using ICTs, were selected in order to analyze their business models and compared these with the models developed for the same services before the integration of such novel technical solutions. Afterwards, we analyzed the results of those eight previous comparisons. This double benchmark methodology allows us to draw conclusions on the most significant differences existing between business models, the ones for conventional public services and those offered using smart technology.

Asking ourselves about the most appropriate way to analyze each of the business models, we found in the literature several suitable frameworks for this kind of business model analysis [66].

During the last few years, Osterwalder's Business Model Canvas has become one of the most popular tools among entrepreneurs. The Business Model Canvas is a framework created for describing, analyzing and designing business models. It was applied and tested in many organizations (e.g. IBM and Ericsson), being successfully used to easily describe and manipulate business models to create new strategic alternatives. Moreover, this framework presents a clear description of the elements comprising a business model [67]. The Canvas comprises nine elements, which cover the four main areas of a business: customers, offer, infrastructure and financial viability. These elements are depicted and described in Table 2.

Table 2. Nine Business Model Building Blocks [54]

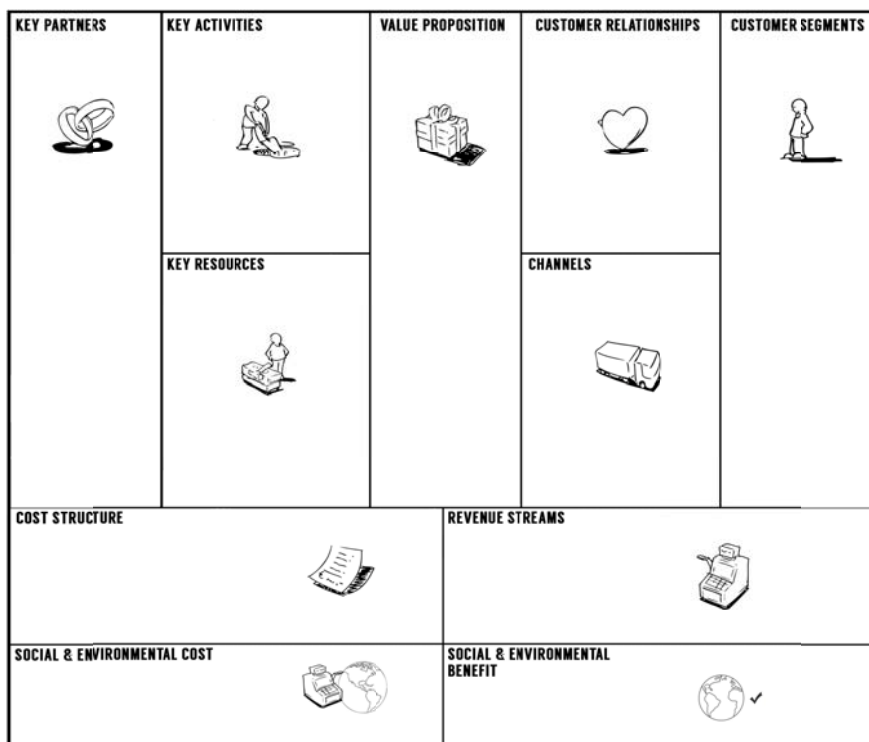
Pillar	Business Model Building Block	Description
Product	Value Proposition	Gives an overall view of a company's bundle of products and services.
Customer Interface	Target Customer	Describes the segments of customers a company wants to offer value to.
	Distribution Channel	Describes the various means of the company to get in touch with its customers.
	Relationship	Explains the kind of links a company establishes between itself and its different customer segments.
Infrastructure Management	Value Configuration	Describes the arrangement of activities and resources.
	Core Competency	Outlines the competencies necessary to execute the company's business model.
	Partner Network	Portrays the network of cooperative agreements with other companies necessary to efficiently offer and commercialize value.
Financial Aspects	Cost Structure	Sums up the monetary consequences of the means employed in the business model.
	Revenue Model	Describes the way a company makes money through a variety of revenue flows.

The Canvas was designed to allow entrepreneurs to analyze their project business models, that is to say, its main function is to help to generate profit. It has also been used for many other purposes hereafter, like for the famous Business Model You [68]. This framework is not that suitable for public administrations as

the provision of an improved quality of life to citizens is usually a priority over the generation of economic benefits. It is for instance the case of smart cities, which pursue social achievements (regarding ageing population, health, etc.) or environmental goals like reducing environmental footprint of their activities [7]. However, some researchers [37] and practitioners have also used the Canvas in the smart city context [69].

The authors of the Canvas also created the Non-Profit Canvas for analyzing non-profit organizations. They recommend to use the framework for non-profits when analyzing business models in public administrations [70], although we have been unable to find any author using it for this purpose in the literature. The main difference between this framework and the original one is that the first one includes two additional parameters, “Social and Environmental Benefit” and “Social and Environmental Cost” (see Figure 1).

Figure 1: Business Model Canvas for Non-Profits [70]



In addition, some researchers have modified the Canvas in order to adapt it to their specific investigations [66,71].

There is also a specific framework to examine business models in smart cities [20,21]. It takes in account the intangible factors of the cities which the authors compress within the concepts control and public value [72].

In order to select the most suitable framework, we relied on the insights collected through in-depth interviews with eleven experts on business plan development and business model design. The in-depth interview method is a widely used qualitative method in exploratory and social research (Bogner *et al.*, 2009; Hill & White, 2000; White & Raman, 1999) that helped us to determine the most appropriate framework to conduct the current analysis. Seven out of the eleven experts recommended the use of the Business Model Canvas or the version for non-profits. The remaining four suggested that there is more than one suitable framework to analyze the business models. However, only one of these four experts stated that the Canvas is not the most appropriate approach. The experts underlined two advantages of the Canvas in comparison to other frameworks: 1) It is the most widely used and recognized method within both the scientific and the professional level, which gives it prestige and, additionally, makes our research more readily understandable to those interested in it; 2) It is a flexible method that allows to fit into it the different specificities of each business model. Hence, we decided to use the Canvas for non-profit organizations.

When analyzing the public services through the Canvas, we should place ourselves in the position of the service provider. However, given that usually several stakeholders participate in the provision of public services (city councils, companies, citizens, etc.) [58,76], we carry out the analysis from the perspective of the aggregation. We use such an approach as we consider the point of view of each stakeholder participating in the provision of the service, as we believe the whole city benefits from this aggregated system of actors with convergent interests. The different agents of the aggregation model share most of the Canvas' parameters and, thus, we take both points of view. However, there are some of such parameters that only influence on one single agent. For instance, in the waste management case there are three main actors taking part in the aggregation (the city council, the company hired to provide the service and the own University of Cantabria). The citizens (users of the service) are the customers of the aggregation but, at the same time, the company will consider the city council as its customer, thus the city council is part of the aggregation as well as any customer. In order to address this question, we have been explicit in the texts of the canvases regarding the factors which only affect to one of the actors.

Afterwards, we have analyzed the business models using the Canvas approach as well as public information available in the CKAN Open Data repository and additional information owned by the Municipality. We have also collected information monitoring how the services are performing. In the case of Santander City Brain, we also interviewed the city official responsible for the service.

We carried out a double benchmarking hereafter. First, we compared the business models of the selected eight public services as they were traditionally operated, with the business models of the same services supported with ICT. The differences between each pair of business models are highlighted in bold letters.

We decided to choose eight services from different sectors to assess the validity of our research and develop action for a wide range of sectors. We strengthened replication logic since pair-wise comparison could be done within a sector resulting in the sector-specific measures [77], and then continued with a cross-sector comparison, producing the generalized measures. This has helped us to connect sector-specific insights to the generic constructs and formulate strong measures that can be generalized across sectors.

Finally, we compared the differences in the eight cases in order to identify the common parameters, discuss the results and address the RQs raised.

The full research process can be summarized in the following chart (Table 3).

Table 3. Process of research work

Action	Literature review	Interviews to experts	Benchmark 1	Benchmark 2	Writing of research paper
Outcome	Selection of the Non-Profit Business Model Canvas and development of a first draft of a method to evaluate business models in smart cities	In-depth interviews to select the proper framework for analyzing performance of business models in smart cities	Case study analysis of 8 public services and comparison between the business models of those traditionally managed and the ones that use ICT technologies	Analysis of the main differences between conventional and smart business models of public services	Final paper with the description of the research work and the conclusions

4. Results

The business models of some of the key public services (waste management, water supply, tourism promotion, traffic management, street lighting, city incidence management, public gardens and parks irrigation system and citizen participation management) relying on conventional operation models are compared with the ones resulting from the integration of ICT technologies. The results have been described in section 4.1. These results were analyzed in a new comparison where the more repeated differences were highlighted, as can be seen in section 4.2.

The methodology used for comparing business models allowed us to underline the differences between the conventional and the new approach. All the main characteristics of the business models were detected with the Business Model Canvas for Non-Profit and the differences among them were clearly highlighted.

4.1. Business Model Analysis of public services

In this subsection, the business models of public services managed with innovative technologies have been compared with those managed conventionally. In the Canvases, the conventional business models

have white background, while business models using innovative technologies are described on a gray background.

4.1.1. Waste management

The Santander City Council is developing a service linked to non-organic waste collection that incorporates the use of the Internet of Things technologies. The city has more than 5,000 sensors to monitor the status of the discharge points (waste containers and bins), which provide information in real time on their location, characteristics and fill levels. The management of this information allows the planning of collecting routes according to the location of full containers, instead of the predefined routes existing in the conventional service. Additionally, both the garbage trucks and other cleaning devices have appliances that gather information about the route followed, the activity carried out and the time involved. This system of smart waste management includes a mobile application called “Cuida Santander”, which allows citizens to know the fill level of bins and containers, the collection routes and timetables, as well as to communicate the service any incident informing about its location. This way users contribute to enhance the service’s efficiency, since the information gathered through the application allows them to plan the appropriate moment to dispose their waste.

Table 4: Canvas for conventional waste management vs. Canvas for waste management with IoT

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - Aggregation service providers (City Council + Concessionaire company) - Truck and container providers. - Processing plant equipment providers. 	<ul style="list-style-type: none"> - Waste collection. - Waste processing. - Recycled waste sales. 	<ul style="list-style-type: none"> - Quality service for waste collection. - Quality service for waste collection, <i>at lower economic costs and less environmental impact.</i> 	<ul style="list-style-type: none"> - Users dispose waste in containers (self-service relation). - Personal and exclusive assistance from the Concessionaire to the City Council. - Users dispose waste in containers (self-service relation). - <i>Users inform about damaged containers using "El pulso de la ciudad" application and managing personal waste based on information from the "Cuida Santander" application.</i> - Personal and exclusive assistance from the Concessionaire to the City Council. 	<ul style="list-style-type: none"> - Users / Citizens. - The City Council, as it is the Concessionaire's client. - The companies that buy waste to process recycled waste are also clients of the Concessionaire.
<ul style="list-style-type: none"> - Aggregation service providers (City Council + Concessionaire company + <i>University of Cantabria as IoT infrastructure manager</i>). - Truck and container providers. - Processing plant equipment providers. - <i>Users, as they inform about damaged containers and manage personal waste using the mobile applications.</i> 	<p>KEY RESOURCES</p> <ul style="list-style-type: none"> - Employees (dustmen and administration staff). - Trucks and containers. - Waste processing plant. - The Concessionaire's previous experience in tender processes for municipal waste management is an asset for future public tenders. 		<p>CHANNELS</p> <ul style="list-style-type: none"> - Promotional materials (corporate website, brochures, advertising...). - News in the media. - E-mails from the citizen's information service at the City Council. - The Concessionaire's sales team is in contact with City Council. 	<ul style="list-style-type: none"> - Users / Citizens. - The City Council, as it is the Concessionaire's client. - The companies that buy waste to process recycled waste are also clients of the Concessionaire.
<p>COST STRUCTURE</p> <ul style="list-style-type: none"> - Employee salaries. - Logistic expenditure (trucks, fuel and containers) - Waste processing plant. 	<ul style="list-style-type: none"> - Employees (dustmen, administration staff and data managers). - <i>Sensors and data management platform.</i> - <i>IoT infrastructure technicians (University of Cantabria).</i> - Trucks and containers. - Waste processing plant. - The Concessionaire's previous experience in tender processes for municipal waste management is an asset for future public tenders. 	<p>REVENUE STREAMS</p> <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the Concessionaire (i.e. the server provider) a subscription fee. - Recycled waste sales. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the Concessionaire (i.e. the server provider) a subscription fee. - Recycled waste sales. 	
<p>SOCIAL & ENVIRONMENTAL COST</p> <ul style="list-style-type: none"> - Energy consumption and environmental impact. 	<ul style="list-style-type: none"> - Energy consumption and environmental impact, <i>but lower than without IoT.</i> 	<p>SOCIAL & ENVIRONMENTAL BENEFIT</p> <ul style="list-style-type: none"> - Job creation to manage the service stimulates economic activity. - A clean city attracts tourism. - Urban healthiness reduces public health problems. 	<ul style="list-style-type: none"> - <i>Lower service cost should allow tax reduction.</i> - <i>Quality job creation to manage the service (highly qualified).</i> - <i>Smart business ecosystem development in the city.</i> - A clean city attracts tourism. - <i>Less energy consumption.</i> - Urban healthiness reduces public health problems. 	

Table 4 shows the results for the analysis using the Business Model Canvas for Non-Profits of waste management services' business models operated conventionally and with IoT technology. We carried out the analysis from the perspective of the aggregation of main actors taking part in the provision of the service, which are the City Council, the concessionaire company which provides the service, and the University of Cantabria whose researchers coordinated the integration of the IoT devices in the smart city infrastructure. Most of the factors described in the Canvas affect all the actors while a few others only affect one of them. We aim at extending the legacy Canvas Model with the different stakeholders active when conceiving a new way to provide urban services as well as to measure the cost and benefits from a social and environmental perspective.

The most significant differences between both models are found in the economic cost and social and environmental cost sections, as the IoT model is cheaper and less polluting.

The service management's tender price proves that the service provided with IoT entails lower costs, as it is a 10% lower than that published in the previous tender process. Moreover, there is an additional 10%

discount in the tender price offered by the winner company of the tender process in 2013, which represents an amount of 15.9 million euros per year for a period of ten years. Therefore, the City Council will spend in the waste management service a 20% less annually compared with the previous tender. The total amount of the contract includes the cost of the researcher's tasks at the University of Cantabria, as this institution receive a small percentage of the contract's value.

Hence, the use of smart devices allows a greater efficiency in the service development, resulting in an optimization of the collection frequency and subsequently improving fuel economy. Dealing effectively with urban waste is key for sustainable city design [78]. Telematic tools allow gathering information from every waste collection point, which can be used to characterize waste production, collection and disposal [79], thus contributing to service and resource optimization.

In addition, the smart model promotes and facilitates direct citizen/user participation in the service management, giving them an active role in the city's sustainable development, in opposition to the conventional model where they are merely service receivers. Furthermore, the smart model allows quality job creation suitable for the analysis and the management of the whole volume of information generated by the smart devices.

4.1.2. Water supply

Water leakages within the Spanish water networks represent an average 21.7% of the total displaced volume. These losses are mainly caused by leaks in pipelines in poor condition or accidents along the distribution system connecting the water collection points and the households. Most of those leakages are not repaired due to poor detection systems.

Santander has implemented the Smart Water project for a smart water management. The project involves the Santander City Council as project coordinator, the University of Cantabria as responsible of IoT's infrastructure management and the FCC Aqualia Company as service provider. The project, being gradually implemented in the city, consists in the integration of sensing and monitoring capabilities of the water distribution network using devices placed on the city distribution pipelines. Those sensors measure water pressure in each section and inform about the network's flow rate at each point, the water level and different water quality parameters. When a significant pressure variation between two points is detected, it is understood that there is a potential leak at that specific network section, therefore the company managing the service repairs it immediately. All this amount of information ensures a balanced management of the supply demand, adapting itself to current and future constraints.

Additionally, Smart Water includes a mobile application that allows users to request a phone call from the water network management company in order to address any supply incidence, receive fault notifications, information on supply disruptions, etc., which may affect them, as well as information about their own consumption curves. This tool facilitates an overall service management, involving the citizen in such process.

Table 5: Canvas for conventional water supply vs. Canvas for water supply with IoT

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - Aggregation service providers (City Council + Concessionaire company) - Maintenance equipment providers. - Aggregation service providers (City Council + Concessionaire company + University of Cantabria as IoT infrastructure manager). - Maintenance equipment providers. - <i>Big data management platform that makes decision-making easier for the service provider.</i> 	<ul style="list-style-type: none"> - Water collection in reservoirs. - Water distribution. - Service monitoring and maintenance. - Water collection in reservoirs. - Water distribution. - Service monitoring and maintenance (including smart sensors and data management). 	<ul style="list-style-type: none"> - Water provision. - Water provision at <i>lower economic and environmental costs.</i> 	<ul style="list-style-type: none"> - Personal assistance to customers. - Customers consume the water they need (self-service). - Concessionaire's relationship with the City Council (personal and exclusive assistance). - Personal assistance to customers. - Customers consume the water they need (self-service). - Concessionaire's relationship with the City Council (personal and exclusive assistance). 	<ul style="list-style-type: none"> - Users / Citizens. - The City Council, as it is the Concessionaire's client. - Users / Citizens. - The City Council, as it is the Concessionaire's client.
	<p>KEY RESOURCES</p> <ul style="list-style-type: none"> - Employees (maintenance and administration staff). - Water collection and distribution facilities. - The Concessionaire's previous experience in tender processes for municipal waste management is an asset for future public tenders. - Employees (maintenance and administration staff, and data managers). - Water collection and distribution facilities. - <i>Sensors and data management platform.</i> - <i>IoT infrastructure technicians (University of Cantabria).</i> - <i>Mobile application.</i> - The Concessionaire's previous experience in tender processes for municipal waste management is an asset for future public tenders. 		<p>CHANNELS</p> <ul style="list-style-type: none"> - The Concessionaire's sales team is in contact with City Council. - Customer service telephone line. - Promotional materials (corporate website, brochures, advertising...). - News in the media. - E-mails from the citizen's information service at the City Council. - The Concessionaire's sales team is in contact with City Council. - Customer service telephone line. - Promotional materials (corporate website, brochures, advertising...). - News in the media. - <i>Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects.</i> - E-mails from the citizen's information service at the City Council. - <i>Mobile application for citizens.</i> 	
<p>COST STRUCTURE</p> <ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure. 	<ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure (including smart sensors and data management team). - <i>University of Cantabria's IoT infrastructure management cost.</i> - <i>* The initial economic investment is bigger due to greater equipment requirements, but in the long term a more efficient technology allows to reduce the overall cost of the service.</i> 	<p>REVENUE STREAMS</p> <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider a subscription fee. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider a subscription fee. 	
<p>SOCIAL & ENVIRONMENTAL COST</p> <ul style="list-style-type: none"> - Water losses, energy consumption and environmental impact. 	<ul style="list-style-type: none"> - Water losses, energy consumption and environmental impact (<i>lower in this case</i>). 	<p>SOCIAL & ENVIRONMENTAL BENEFIT</p> <ul style="list-style-type: none"> - Job creation to manage the service stimulates economic activity. - Urban healthiness reduces public health problems. 	<ul style="list-style-type: none"> - <i>Lower service cost should allow tax reduction.</i> - <i>Quality job creation to manage the service (highly qualified).</i> - <i>Smart business ecosystem development in the city.</i> - <i>Less energy and water consumption.</i> - Urban healthiness reduces public health problems. 	

The Business Model Canvas (Table 5) allowed us to compare the municipal waste management business model operating since the application of IoT technologies with the previous model, which remains the most common one among Spanish cities. Regarding the smart service, the key actors' aggregation is composed of the three agents mentioned above (the City council, the service provider company, and the research institution managing the smart technologies). On the other hand, there is no research institution engagement in the conventional model. Among other differences, it should be highlighted that the service offered using ICT requires new key resources (sensors, data management technicians and a mobile

application available for customers) that increase costs. However, cost savings due to fewer water losses are also expected. The City Council has concluded that, although the new model involves greater initial investments, the overall cost will be lower through a reduction in water consumption. However, there are not current data to support that statement.

Furthermore, there is a significant reduction in water leakage and energy consumption by means of the sensor system, resulting in the mitigation of environmental impacts. In addition, the smart system entails other social benefits to take into consideration, as quality job creation to manage the technology and the boost of an ecosystem in Santander for companies within the sphere of activity of the smart cities that support these initiatives and that use the acquired know how in order to offer their products and services to other cities.

4.1.3. Tourism promotion

Tourism is a key sector for Santander's economy, thus the city assigns a significant part of its budget to tourism promotion. There are stands across the city to inform about tourist attractions and to hand out brochures detailing the tourist offer. Moreover, two years ago it was launched the SmartSantanderRA mobile application for Android and iOS, which has been downloaded by more than 24,000 citizens.

This free application provides information about different buildings and other cultural features of the city. The application works pointing a mobile device towards, for instance, a landmark building. The application will display an augmented reality image of the building, as well as information about its history, characteristics and further visual media. The application offers information of around 200 touristic landmarks in Santander, in addition to other sections as a cultural agenda with geolocated incidences; urban transport information highlighting the closest bus stops, the lines and the distance of the next buses; nearest taxi queues, underground parking lots and bike loan points. Additionally, aiming to enrich the application, 2,600 dual tags (NFC and QR) have been deployed in bus stops and business. Moreover, local business can add their information to the application data as well.

Table 6: Canvas for conventional tourism promotion vs. Canvas for tourism promotion with augmented reality

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - City Council. - Content providers and brochure producers. - Public buildings for brochure distribution. 	<ul style="list-style-type: none"> - Main city buildings description. - Brochure production. - Attract advertisers. 	<ul style="list-style-type: none"> - Portable tourist information financed by advertising spaces for major companies. 	<ul style="list-style-type: none"> - Personal assistance to tourists and citizens. - Self-service of brochures and published information. 	<ul style="list-style-type: none"> - Tourists. - Santander citizens. - Major companies (advertisers).
<ul style="list-style-type: none"> - Aggregation service providers (City Council + University of Cantabria as mobile application developer) - Content providers and brochure producers. - Public buildings for brochure distribution. 	<ul style="list-style-type: none"> - Main city buildings description. - Brochure production (lower than in the conventional mode because some users will use the mobile application exclusively). - Mobile application development and maintenance - Attract advertisers. 	<ul style="list-style-type: none"> - Portable and geolocated tourist information financed by advertising spaces for major companies and small business, resulting in increased revenues and cost reductions due to lower brochure production. 	<ul style="list-style-type: none"> - Personal assistance to tourists and citizens. - Self-service of brochures and published information. - Self-service relation using the mobile application. 	<ul style="list-style-type: none"> - Tourists. - Santander citizens. - Major companies (advertisers). - Small and local businesses (advertisers).
	KEY RESOURCES <ul style="list-style-type: none"> - Employees. - Stands. - Budget to publish brochures. 		CHANNELS <ul style="list-style-type: none"> - Information stand's staff in key city areas. - Brochure hand out. - Tourist information website. - E-mails from the citizen's information service at the City Council. - News and adverts in the media. 	
	<ul style="list-style-type: none"> - Employees. - Stands. - Budget to publish brochures (* It is expected that a lower number of brochures will be printed than in the conventional model because some users will use the mobile application exclusively). - Sensors and data management platform. - Data management technicians (University of Cantabria). - Mobile application. 		<ul style="list-style-type: none"> - Information stand's staff in key city areas. - Brochure hand out. - Tourist information website. - Mobile application for citizens and tourists. - Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects. - E-mails from the citizen's information service at the City Council. - News and adverts in the media. 	
COST STRUCTURE <ul style="list-style-type: none"> - Employee salaries. - Brochure production. 	<ul style="list-style-type: none"> - Employee salaries. - Brochure production (*It is expected a lower economic cost than in the conventional model due to lesser production). - University of Cantabria's IoT infrastructure and data management service cost for application development and maintenance. - * An increased revenue will likely generate greater benefit compared with the conventional model. 	REVENUE STREAMS <ul style="list-style-type: none"> - Indirect taxes paid by tourists. - Other taxes. - Entrance fees to public buildings. - Major companies advertising in brochures. 	<ul style="list-style-type: none"> - Indirect taxes paid by tourists. - Other taxes. - Entrance fees to public buildings (greater than in the conventional model because the Augmented Reality allows promoting visits to public buildings). - Major companies advertising in brochures. - Advertising of major companies and small businesses through the mobile app. 	
SOCIAL & ENVIRONMENTAL COST <ul style="list-style-type: none"> - Brochure production represents energy consumption and CO2 emissions. 	<ul style="list-style-type: none"> - The fewer number of brochure printed reduces energy consumption and CO2 emissions. 	SOCIAL & ENVIRONMENTAL BENEFIT <ul style="list-style-type: none"> - Tourism and economic activity stimulation. - Cultural education for citizens. 	<ul style="list-style-type: none"> - Tourism and economic activity stimulation. - Cultural education for citizens. - Increased revenues and lower service cost should allow tax reduction. - Smart business ecosystem development in the city. - Less energy consumption and reduced environmental impact as less promotional materials are printed. 	

Table 6 shows the differences between the conventional tourism promotion model, based mainly on portable brochures, and the one built around the SmartSantanderRA application. The City Council and the University of Cantabria form the aggregation of actors taking part in the provision of the service. The value proposition of the information system using printed brochures offers portable tourist information financed by advertising spaces purchased by major companies. On the other hand, the SmartSantanderRA proposition adds geolocated information, as well as geolocated advertising opportunities for both major and small businesses. Hence, the mobile application increase its revenue sources by adding a new type of customer (small businesses) and by promoting tourist visits to public buildings that charge entrance fees.

Regarding the cost, the application needs to cover the cost of a new key resource, the University of Cantabria's researchers, who are responsible for the application design and maintenance. However, the application availability should imply a lesser use of brochures and, therefore, a cost reduction, although there is not data supporting this assumption. This brochure cost reduction, combined with greater

advertising revenues, would make the launch of the application profitable. The SmartSantanderRA application was designed by the University of Cantabria in collaboration with the Santander City Council as part of the SmartSantander European research project, whose setting up was funded by the EU.

The fall in the production of printed brochures entails energy savings and, therefore, a reduction in CO₂ emissions to the atmosphere, thus the transition to a tourism promotion model that uses the application reduces the environmental impact. Among social benefits, it should be highlighted that being SmartSantanderRA an innovative application, it helps to set the city as a smart city, creating a positive perception for both citizens and tourists and fostering the development of an ecosystem for technological business in the city. Additionally, the savings related with the use of the application should allow future tax reductions or greater investment in other budget headings.

4.1.4. Traffic management

The transport sector in the EU is responsible for approximately 30% of total energy consumptions and the 27% of total greenhouse gas emissions [80]. Additionally, traffic accidents and congestion impose an important economic burden to the society [81], which makes urgent a rationalization of urban processes to improve the quality of life, energy saving and the sustainability of the planet [82].

A network of fixed and mobile smart sensors has been added to the conventional Santander's traffic management. Those sensors enable monitoring traffic parameters such as its intensity, traffic density, speed of the vehicles or queue sizes, allowing, after being integrated in a control center, carry out a more efficient urban traffic management and enabling real-time responses to changing circumstances. The control center also integrates the city's traffic light system management, as well as the control panel management of 400 parking spaces and all the information related to public transport. There are also mobile IoT devices deployed on public transport vehicles equipped with GPS, so that all their observations are geolocalized and they also report speed and course of the vehicle providing information that is used to feed the traffic assessment service [14]. Additionally, there have been developed web and mobile applications that allow an easy and effective access to traffic conditions in real-time for all users, so they can choose the best route to get to their destination, thus participating actively in the city's traffic management.

Table 7: Canvas for conventional traffic management vs. Canvas for smart traffic management

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - City Council. - Spanish traffic authority. - Aggregation service providers (City Council + University of Cantabria as data manager and IoT infrastructure manager) - National traffic authority. - Taxis and buses, as they are mobile sensors. - Information management through the big data platform and its managers. - Big data management platform that makes decision-making easier for the service provider. 	<ul style="list-style-type: none"> - Traffic information collection (police agents patrolling the city, conventional cameras, incidents communicated by citizens). - Information management at the control centre. - Traffic management based on the information collected. - Traffic information collection (police agents patrolling the city, conventional cameras, incidents communicated by citizens, smart sensors). - Information management at the control centre using the platform for big data. - Traffic management based on the information collected (including that which was collected by the new sensors). - Traffic information transmission to users in real-time using the mobile application. 	<ul style="list-style-type: none"> - City traffic monitoring and management based on information transmitted by traffic wardens, other civil servants, conventional cameras and citizen phone calls. - City traffic monitoring and management based on information transmitted by traffic wardens, other civil servants, conventional cameras and citizen phone calls, as well as by sensors for big data management in real-time. - Citizens can check in real-time all the information in their mobile phones and, thus, actively participate in the traffic management based on their own interest. 	<ul style="list-style-type: none"> - Public information through a self-service relation. - Public information through a self-service relation using more channels. 	<ul style="list-style-type: none"> - Users / Citizens. - Users / Citizens.
	<p>KEY RESOURCES</p> <ul style="list-style-type: none"> - Civil servants (police agents, control centre technicians, etc.). - Communication systems with the traffic control centre. - Conventional cameras. - Civil servants (police agents, control centre technicians, etc.). - Communication systems with the traffic control centre. - Conventional cameras. - Fixed and mobile smart sensors and data management platform. - Data management and IoT infrastructure technicians (University of Cantabria). - Mobile application for users. 		<p>CHANNELS</p> <ul style="list-style-type: none"> - Local police (personal relation with users). - Spanish traffic authority website. - News and adverts in the media. - E-mails from the citizen's information service at the City Council. - Local police (personal relation with users). - Spanish traffic authority website. - News and adverts in the media. - E-mails from the citizen's information service at the City Council. - Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects. - Mobile application for citizens. - Parking information boards. 	
<p>COST STRUCTURE</p> <ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure. 	<ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure, being initially higher due to new smart equipment requirements such as sensors or the big data management platform. - University of Cantabria's IoT infrastructure maintenance and data management service cost. 	<p>REVENUE STREAMS</p> <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 	
<p>SOCIAL & ENVIRONMENTAL COST</p> <p>N/A</p>	<p>N/A</p>	<p>SOCIAL & ENVIRONMENTAL BENEFIT</p> <ul style="list-style-type: none"> - Job creation to manage the service stimulates economic activity. 	<ul style="list-style-type: none"> - Greater citizen satisfaction due to more traffic fluidity and more information. - Less energy consumption and reduced environmental impact. - Quality job creation to manage the service (highly qualified). - Smart business ecosystem development in the city. 	

We used the Business Model Canvas framework in order to compare the business model operating the traffic management after the integration of IoT technologies with the legacy conventional model (Table 7). The current model, involving and intensive use of ICT, introduces a higher quality and a more comprehensive value proposition since both the traffic managers and service users have more information about traffic conditions to make their decisions. For that purpose, this model rely on new resources such as smart sensors, the data management platform and the mobile application for users, as well as on new channels as the application itself and traffic information panels located in the streets. The setting up of this system involve the participation of new agents such as the researchers from the University of Cantabria, responsible for the managing the IoT infrastructure including the technological platform and data collected from the taxis fleet and the local buses, since both ambos vehicle types carry mobile sensors that provide traffic information in real-time. The City Council and the research institution are considered the stakeholder's aggregation responsible for managing the smart system.

The cost structure of the smart system for traffic management requires an initial investment that in the case of Santander is covered by the SmartSantander research project.

The higher quality service results in a greater citizen satisfaction associated to more traffic fluidity and the availability of information. Both are social benefits, as well as the creation of quality and highly qualified jobs for technology management and the development in Santander of an ecosystem for companies that offer products and services for smart cities. Moreover, a well-managed traffic requires less energy consumption and reduces the environmental impact.

4.1.5. Street lighting

As street lighting represents a 2.3% in global electricity consumption in the world and since possibilities for energy savings in the streets are numerous, being some of them able to reduce electricity consumption in even more than a 50% [83], efficient energy programs in this field are welcomed.

Santander used to have a conventional street lighting system and it is currently deploying a more efficient system that relies on the use of LED technology. The infrastructure incorporates a point-to-point monitoring and command system (node status, whether it is connected to the network or not; battery power; luminosity level), or to regulate the light intensity, to reprogram new actions. Light intensity is not uniform across the city, it is adjusted according to whether the luminary is placed in a commercial or touristic area (30-35 lux), a main street (25-30 lux), a secondary street (20-25 lux) or a park or any other area (minimum 15 lux). The company awarded in the public tender (Elecnor) will perceive an amount of 34.3 million euros during a period of 15 year. The concessionaire will cover an initial investment of 11 million euros to replace the existing 22,700 luminaires in the city. In Santander, the annual street lighting expenditure used to be around 2.5 or 3 million euros, including the electricity consumption. The proposed management model implies the distribution of profits; therefore the 65% projected savings will be shared allocating a 60% for the company and a 40% for the City Council. The new system aims to reduce CO2 emissions by 2.4 million kilograms per year

Table 8: Canvas for conventional street lighting vs. Canvas for smart street lighting

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - City Council. - Energy supplier. 	<ul style="list-style-type: none"> - System planning. - Facility maintenance. 	<ul style="list-style-type: none"> - Lighting system for all city areas. 	<ul style="list-style-type: none"> - Light usage in public spaces through a self-service relation. 	<ul style="list-style-type: none"> - Citizens.
<ul style="list-style-type: none"> - Aggregation service providers (City Council + University of Cantabria as data manager and IoT infrastructure maintenance manager) - Energy supplier. - Company that designed the city lighting strategic plan. 	<ul style="list-style-type: none"> - System planning. - Facility maintenance. - Data management of information collected by sensors through the big data platform. 	<ul style="list-style-type: none"> - Lighting system for all city areas at lower economic costs and less environmental impact, with a slight reduction of the illumination level when pedestrians are not passing under the streetlights. 	<ul style="list-style-type: none"> - Light usage in public spaces through a self-service relation. 	<ul style="list-style-type: none"> - Citizens.
	KEY RESOURCES <ul style="list-style-type: none"> - Civil servants. - Luminaries and other facilities. - Energy supply. 		CHANNELS <ul style="list-style-type: none"> - Promotional materials (corporate website, brochures, advertising...). - News in the media. - E-mails from the citizen's information service at the City Council. 	
	<ul style="list-style-type: none"> - Civil servants. - Luminaries and other facilities. - Energy supply. - Motion sensors and data management platform. - Data management and IoT infrastructure technicians (University of Cantabria). 		<ul style="list-style-type: none"> - Promotional materials (corporate website, brochures, advertising...). - News in the media. - E-mails from the citizen's information service at the City Council. - Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects. - A specific communication plan tailored for the service is projected. 	
COST STRUCTURE <ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure, being initially higher due to new LED and sensor equipment requirements. - Energy supply, being its cost an 80% lower because the technology is more efficient. - University of Cantabria IoT infrastructure maintenance and data management service. - * The initial economic investment is bigger due to greater equipment requirements, but in the long term a more efficient technology allows to reduce the overall cost of the service. 		REVENUE STREAMS <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 		<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider.
SOCIAL & ENVIRONMENTAL COST <ul style="list-style-type: none"> - Energy consumption and environmental impact. 	<ul style="list-style-type: none"> - Energy consumption and environmental impact, but lower than without IoT. - Slight reduction of the illumination level during the period of enabled lighting if nobody walks under the streetlights 	SOCIAL & ENVIRONMENTAL BENEFIT <ul style="list-style-type: none"> - High illumination level during the whole period of enabled lighting. - Job creation to manage the service stimulates economic activity. 		<ul style="list-style-type: none"> - Lower service cost should allow tax reduction. - Less energy consumption and reduced environmental impact. - Quality job creation to manage the service (highly qualified). - Smart business ecosystem development in the city.

Table 8 shows business model differences between the conventional street lighting system and the one being currently implemented. It indicates that, even though the smart street lighting model requires a higher economic investment in sensor and LED technology in the short-term, it is counterbalanced in the long-term by its greater energy efficiency, life span and low maintenance requirements, all of which may represent consumption savings of up to 80%.

The adoption of these new technologies implies energy savings and significant CO₂ emission reductions, which constitutes an environmental benefit for the city. Among many social benefits, it should be highlighted that the installation and maintenance of these new technologies require the presence of qualified professionals in the city that subsequently can export their experience to other cities. Therefore, it is being generated in Santander an ecosystem of specialized companies that offer products and services for smart cities. Additionally, once the new technology has been amortized in the long-term, it should allow tax reductions or to devote more resources to other activities.

On the other hand, the legacy solutions offer permanent lighting level even when there is not pedestrian transit. As stated previously, this represents an economic and energy cost, but also enables greater visibility, which is a benefit, although of lesser importance for being favorable just in very exceptional circumstances.

In order to launch this new street lighting system, the Santander City Council established partnership with the University of Cantabria, which initially developed a pilot trial with a lighting system using sensors in parks as part of the SmartSantander scientific project. A consulting firm carried out a strategic analysis of the city's lighting infrastructure, and Viesgo is the energy provider in the municipality.

4.1.6. City incidence management

The conventional incidence management system in Spanish cities comprise civil servants (police agents, fire-fighters, maintenance workers, town planning technicians, etc.) monitoring incidences and reporting them to the appropriate service for their correction. In addition, Santander has enabled since 2012 a participatory sensing system called “El pulso de la ciudad” through which citizens are able to inform about incidents occurring across the city using a mobile application [11]. Any citizen can report, share and be notified events happening in the city taking a picture of the incidence and geolocating it to report civil servants and other platform users. Hence, the Santander City Council's civil servants can receive an early warning of the incidence, as this system complements the conventional one. On the other hand, the open access publication of the incidence provides an incentive to local civil servants, who reported that the troubleshooting period has been decreasing gradually since the launch of the application. Likewise, anyone can report traffic accidents, etc., alerting both authorities and other drivers.

The “El pulso de la ciudad” platform was developed by the University of Cantabria researchers as part of the SmartSantander scientific project. In addition to the university, which is the platform administrator, and the Santander City Council, which manages the incidences, the regional newspaper, El Diario Montañés, also participates in this project. It manages the web version of the platform and has been actively involved in the promotion of the mobile application. To date, the “El pulso de la ciudad” mobile application has been downloaded 8,400 times in Android and iOS devices.

Table 9: Canvas for conventional city incident management vs. Canvas for city incidence management including “El pulso de la ciudad”

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - City Council. - Equipment providers. - Citizens reporting. 	<ul style="list-style-type: none"> - Incidence information collection by civil servants across the city y by citizen communication via email. - Incidence information management. - Troubleshooting. 	<ul style="list-style-type: none"> - Conventional system for city incidence management. 	<ul style="list-style-type: none"> - Instance request to the City Council via e-mail. 	<ul style="list-style-type: none"> - Citizens.
<ul style="list-style-type: none"> - Aggregation service providers (City Council + <i>University of Cantabria as data and mobile manager application development and management + El Diario Montañés as web application manager</i>). - Equipment providers. - Citizens reporting, <i>being more relevant and active in this case for having a specific mobile application.</i> 	<ul style="list-style-type: none"> - Incidence information collection by civil servants across the city and a <i>more active citizen engagement using the new channels.</i> - <i>Mobile application maintenance and management.</i> - Incidence information management. - Troubleshooting. 	<ul style="list-style-type: none"> - <i>Highly efficient and easy to use system for city incidence management that fosters citizen engagement.</i> 	<ul style="list-style-type: none"> - Instance request to the City Council via e-mail. - <i>Communication through the mobile application.</i> 	<ul style="list-style-type: none"> - Citizens.
	KEY RESOURCES <ul style="list-style-type: none"> - Civil servants. - Technical and logistical equipment for troubleshooting. 		CHANNELS <ul style="list-style-type: none"> - City Council's website. - News in the media. - E-mails from the citizen's information service at the City Council. 	
	<ul style="list-style-type: none"> - Civil servants. - <i>Data management and IoT infrastructure maintenance technicians (University of Cantabria).</i> - <i>Sensors and data management platform.</i> - Technical and logistical equipment for troubleshooting. - <i>"El pulso de la ciudad" mobile and web application for users.</i> 		<ul style="list-style-type: none"> - City Council's website. - News in the media. - E-mails from the citizen's information service at the City Council. - <i>Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects.</i> - <i>"El pulso de la ciudad" mobile and web application for users.</i> 	
COST STRUCTURE <ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure. 	<ul style="list-style-type: none"> - Employee salaries. - Investment in facilities and maintenance expenditure. - <i>Mobile application development.</i> - <i>University of Cantabria's IoT infrastructure maintenance and data management service cost.</i> - <i>Web application managers (El Diario Montañés).</i> 	REVENUE STREAMS <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. - <i>Advertising at the El Diario Montañés website.</i> 	
SOCIAL & ENVIRONMENTAL COST <p>N/A</p>	<p>N/A</p>	SOCIAL & ENVIRONMENTAL BENEFIT <p>N/A</p>	<ul style="list-style-type: none"> - <i>It is expected that citizens perceive greater service efficiency because they know the incidence situation in real-time.</i> - <i>Lower service cost due to citizen engagement should allow tax reduction.</i> - <i>Smart business ecosystem development in the city.</i> - <i>Less energy consumption and reduced environmental impact due to a lesser need of civil servants moving around the city to monitor incidences.</i> 	

Using the Canvas framework, we have compared the business model of the conventional system for incidence management with the system that incorporates de use of the SmartSantander platform (Table 9). The new system offers a value proposition that implies a more efficient system, adding citizen engagement to those tools used previously in the conventional system. The main source of revenue is the municipal budget. As the application was originally a research project funded by the EU, its development did not involve any cost for the City Council. On the other side, El Diario Montañés contributes hosting the platform and benefiting from the visits that it generates, which represent more revenues via online advertising.

Among social benefits, it should be highlighted that the citizens should perceive a greater service efficiency because they know the incidence situation in real-time, there is less energy consumption and environmental cost as there is a lesser need for civil servants to move across the city monitoring incidences due to citizen engagement in the process, freeing up the civil servants to focus on other tasks.

The launch of this innovative technology contributes to generate an ecosystem in the city for specialized business on smart cities that employs highly qualified professionals.

In the cost structure of the new system it must be added the application development as well as its maintenance.

In the key partners section are included the Santander City Council, responsible for the incident management service; the University of Cantabria, which has developed and manages the mobile platform; the company owning El Diario Montañés, which hosts the web version of the platform and promotes the application among its readers; and the citizens, who are the ones reporting incidences.

4.1.7. Public garden and parks irrigation system

Water used in urban landscape irrigation has been documented to reach 56% of the total water use in cities [84], hence the need for smart technologies that lead to a sustainable water consumption in urban public gardens. Advanced irrigation controllers exhibit significant reductions in water use when compared with manual irrigation or irrigation with standard time controllers [85]. Wireless smart sensor arrays for measuring soil moisture and temperature permits fine scheduling irrigation for further water savings [86].

Santander has developed and integrated a precision irrigation service that estimates plants' requirements in water for different areas using IoT nodes equipped with sensors measuring parameters like air temperature and humidity, soil temperature and moisture, atmospheric pressure, solar radiation, wind speed/direction and rainfall [13]. The information collected in real time allows park technicians to adjust irrigation strategies at any given time. Instead of taking decisions based on average conditions or having to be constantly physically present on-site, a precision park irrigation approach recognizes differences and accordingly automates management actions. Additionally, this service makes use of, both, web and mobile applications, which provide easy access to the measured parameters inside the park and garden areas. The system was tested within the SmartSantander scientific project for the first time, enabling the University of Cantabria researchers to obtain the know-how.

When the conventional system was in place, gardeners moved across the city in order to monitor moisture in gardens and parks and, therefore, make the decision of whether or not operate the irrigation system.

Table 10: Canvas for conventional gardens and parks irrigation vs. Canvas for gardens and parks irrigation with IoT

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - Aggregation service providers (City Council + Concessionaire company). - Equipment providers and irrigation system maintenance. - Vehicle providers for gardeners that monitor moisture in gardens and parks. 	<ul style="list-style-type: none"> - Gardeners visiting green spaces in the city to monitor moisture in gardens and parks. - Facility maintenance. - Green spaces irrigation. 	<ul style="list-style-type: none"> - Gardens and parks maintenance service. - Gardens and parks maintenance service, <i>at lower economic costs and less environmental impact.</i> 	<ul style="list-style-type: none"> - Personal and exclusive assistance from the Concessionaire to the City Council. - Users enjoy parks through a self-service relationship. 	<ul style="list-style-type: none"> - Users / Citizens. - The City Council, as it is the Concessionaire's client.
<ul style="list-style-type: none"> - Aggregation service providers (City Council + Concessionaire company + <i>University of Cantabria as IoT infrastructure and data manager</i>). - Equipment providers and irrigation system maintenance. 	<p>KEY RESOURCES</p> <ul style="list-style-type: none"> - Employees (gardeners and administration staff). - Irrigation facilities and equipment. - Water to be supplied. - The Concessionaire's previous experience in tender processes for municipal waste management is an asset for future public tenders. 		<p>CHANNELS</p> <ul style="list-style-type: none"> - The Concessionaire's sales team is in contact with City Council. - Promotional materials (corporate website, brochures, advertising...). - News in the media. 	<ul style="list-style-type: none"> - Users / Citizens. - The City Council, as it is the Concessionaire's client.
<p>COST STRUCTURE</p> <ul style="list-style-type: none"> - Employee salaries. - Logistic expenditure (vehicles). - Water supply. 	<ul style="list-style-type: none"> - Employee salaries. - <i>Logistic expenditure (vehicles), being radically lower because it does not require daily on-site monitoring of green spaces.</i> - <i>University of Cantabria IoT infrastructure and data management service cost.</i> - <i>Smart sensors and data management platform.</i> - Water supply, <i>being lower because a more accurate moisture monitoring allows reducing water consumption.</i> - <i>* It is expected that a more cost-efficient smart system because the reduction in water and energy (vehicles) consumption clearly outweighs the investment in IoT technologies.</i> 	<p>REVENUE STREAMS</p> <ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the server provider. 	
<p>SOCIAL & ENVIRONMENTAL COST</p> <ul style="list-style-type: none"> - Energy consumption and environmental impact. 	<ul style="list-style-type: none"> - Energy consumption and environmental impact, <i>but lower than in the conventional system.</i> 	<p>SOCIAL & ENVIRONMENTAL BENEFIT</p> <ul style="list-style-type: none"> - Job creation (gardeners and managers) stimulates economic activity. 	<ul style="list-style-type: none"> - Job creation (gardeners and managers) stimulates economic activity. - <i>Quality job creation to manage the service (highly qualified).</i> - <i>Lower service cost due to citizen engagement should allow tax reduction.</i> - <i>Smart business ecosystem development in the city.</i> - <i>Less energy and water consumption and reduced environmental impact.</i> 	

We used the Business Model Canvas in order to compare the irrigation system business model using IoT technologies against the conventional system (Table 10). We carried out the analysis from the perspective of the aggregation of the main actors, including the City Council, the concessionaire company whose gardeners work in the gardens (UTE Piñera - Urbaser), and the University of Cantabria whose researchers are in charge of managing the IoT infrastructure. At the moment, the University is also managing the data but in the future the concessionaire company will assume this task. Most of the factors described in the Canvas affect the full aggregation while there is a few that only affect one of the actors.

The new model value proposition comprises a more cost-effective and environmentally friendly gardens and parks irrigation system management than the conventional one. Hence, although new investment cost must be considered, such as smart sensors, the data management platform, the University of Cantabria data management staff or maintenance expenditure, there are also significant savings such as lower water consumption and reduced logistic expenditure, since technicians do not need to use vehicles to perform daily on-site moisture measurements. The service is being currently implemented and there are not

official data available about costs or amortization periods. However, the City Council forecast a return on investment for the IoT model in the medium-term.

The creation of highly qualified jobs for data management is a social benefit that must be noted. This enables an ecosystem generation for companies and professionals specialized on IoT technologies and smart City management.

Regarding to environmental benefits, it should be highlighted the water savings this technology allows, since irrigation is enabled only when it is really needed. Moreover, a lesser need for on-site monitoring also allows a lower energy consumption that reduces CO₂ emissions to the atmosphere.

4.1.8. Citizen engagement management

Santander has a population of 178,456 [87] and is located in the north coast of Spain. Communication between the municipality government and the citizens has been carried out mainly through community associations and civil society organizations such as unions or employer federations. Additionally, the city enjoys the Santander City Brain tool since 2013, which is designed to enable citizen engagement and idea generation focused on city improvement.

Santander City Brain is a user-driven tool and idea generations are proposed by the City Council. Most times, participation is fostered through idea competitions that are launched on the platform. The rules of the competition stipulate that the 10 most voted ideas by the community of users go over to the final phase and, afterwards, a panel made up of members of the City Council selects the winner. In addition, the Mayor of Santander has published two queries from his own user profile. Both questions aim to gain knowledge on the public's opinion about issues of municipal management.

Table 11: Canvas for Citizen Engagement management vs. Canvas for Citizen Engagement management with Santander City Brain

KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITION	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
<ul style="list-style-type: none"> - City Council. - City Council's communication equipment providers. - Aggregation service providers (City Council + Ideas4All as the company managing the Santander City Brain social network). - City Council's communication equipment providers. - Santander City Brain sponsor companies (IBM and Banco Santander). - Citizens engaging in public policies through the mobile application. 	<ul style="list-style-type: none"> - Information gathering via citizen suggestions communicated by e-mail. - Incidence information management. - Decision-making. - Web and media broadcast of open consultations to citizens on urban improvement projects. - Information gathering via citizen suggestions communicated by e-mail and the Santander City Brain social network. - Incidence information management. - Decision-making. 	<ul style="list-style-type: none"> - Conventional management of citizen engagement in political decision-making, through community associations and civil society organizations. - Conventional management of citizen engagement in political decision-making, through both the conventional channels and an online social network promoted by local authorities which fosters a direct link between governing and those governed. 	<ul style="list-style-type: none"> - On-site meetings with City Council officials, mainly with institutions or citizen associations. - Instance request to the City Council via e-mail. - On-site meetings with City Council officials, mainly with institutions or citizen associations. - Instance request to the City Council via e-mail. - Brainstorming through the Santander City Brain social network. <p>CHANNELS</p> <ul style="list-style-type: none"> - Meetings between City Council officials and community associations and other representatives of different groups (e.g. employer federations, etc.). - E-mails from the citizen's information service at the City Council. - Meetings between City Council officials and community associations and other representatives of different groups (e.g. employer federations, etc.). - E-mails from the citizen's information service at the City Council. - Public conferences, workshops, hackathons, and other activities to disclosure information about Santander's smart city projects. - Santander City Brain social network. 	<ul style="list-style-type: none"> - Citizens. - Citizens.
COST STRUCTURE		REVENUE STREAMS		
<ul style="list-style-type: none"> - Civil servant salaries. - Investment and City Council communication equipment's maintenance cost 	<ul style="list-style-type: none"> - Civil servant salaries. - Investment and City Council communication equipment's maintenance cost - Santander City Brain social network development, funded by IBM and Banco Santander sponsorship. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the service. 	<ul style="list-style-type: none"> - The City Council uses collected taxes to pay the service. - Corporate sponsoring (IBM and Banco Santander). 	
SOCIAL & ENVIRONMENTAL COST		SOCIAL & ENVIRONMENTAL BENEFIT		
N/A	N/A	N/A	<ul style="list-style-type: none"> - Citizens have broader options and encouragement for public policy engagement. - Improvement on public policies because there are more people involved in their development. - Smart business ecosystem development in the city. 	

Table 11 shows the analysis that compares the business model of the conventional citizen engagement management system, which operates through communication between local government officials with civil society organizations, and the one that combines the conventional model with the Santander City Brain tool. The value proposition of the new model stands out for fostering a closer relationship between government and citizens by means of an efficient and organized system, since the citizens can share their opinions and ideas directly to the authorities without having to go through the filter of civil society organizations. Hence, the new channel, i.e. the Santander City Brain social network.

Among social benefits of the new system, it should be noted the boost to citizen political engagement, which is characterized as a positive aspect by several authors [88], as well as the expected improvement in policies, since more ideas are taken into account [89]. Additionally, this project contributes to produce in Santander an ecosystem of business specialized in products and services for smart cities.

IBM and ISBAN (a subsidiary company of Santander Bank focused on software engineering) granted the project 70,000 and 30,000 euros, respectively, as they pursue both developing a community partnership action and collaborate in the Santander's smart city environment. This amount includes the development of the social network as well as the salary of its community manager.

Santander City Brain is an official social media tool and belongs to the Santander City Council. It is a *public-private partnership* project (PPP), as the firms IBM, ISBAN and Ideas4All also take part in the project. IBM and ISBAN defray the project whereas Ideas4All developed the technological platform and manages the community of users, i.e. is the community manager. The Santander City Council, as main decision maker of the project, is responsible of proposing the topic of the ideas to be asked to the community.

4.2. Differences between conventional and smart business models of public services

The business models of public services managed with innovative technologies differ many times from those managed conventionally. Many of those differences are repeated in several of the eight cases studied. The most significant and common features that the new management systems incorporate to the business models have been described in Table 12.

Table 12: Most repeated differences between business models of public services

Most repeated features	Services provided with innovative technologies which include these features	Number of times repeated
Service of the same quality or above	Waste management, Water supply, Tourism promotion, Traffic management, City incident management, Gardens and parks irrigation, Citizen Engagement Management	7
More actors involved in the management of the service	Waste management, Water supply, Tourism promotion, Traffic management, Pubic lighting, City incident management, Gardens and parks irrigation, Citizen Engagement management	8
Lower costs in the long term	Waste management, Water supply, Tourism promotion, Pubic lighting, City incident management, Gardens and parks irrigation	6
Some initial investment required	Waste management, Water supply, Tourism promotion, Traffic management, Pubic lighting, City incident management, Gardens and parks irrigation, Citizen Engagement management	8
Use of Big Data for decision-making	Waste management, Water supply, Tourism promotion, Traffic management, Pubic lighting, Gardens and parks irrigation	6
Users are provided with more information of the service	Waste management, Water supply, Tourism promotion, Traffic management, City incident management, Citizen Engagement management	6
Reductions in energy and/or water consumption	Waste management, Water supply, Tourism promotion, Traffic management, Pubic lighting, City incident management, Gardens and parks irrigation	7
Contributes to foster an ecosystem of IT businesses and professionals in Santander	Waste management, Water supply, Tourism promotion, Traffic management, Pubic lighting, City incident management, Gardens and parks irrigation, Citizen Engagement management	8

5. Discussion

The research methodology developed allowed us to analyze and compare business models. The Business Model Canvas for Non Profit framework was useful to describe business models in smart cities. It helped to highlight important aspects that the original Business Model Canvas does not take into account, like the social and environmental issues.

The results of the current research highlight that the municipal services that makes an intensive use of smart technologies generally display a value proposition focused on service efficiency, which results in lower economic costs and reduces environmental impacts when compared with those of the conventional provision systems for the same service. The new services are always of the same quality or above, because they increase the efficiency while not dropping the conventional methods completely, which helps to supplement the innovative approach. On the other hand, the value propositions include in a number of cases an improvement in the information provided to the users and, sometimes, they even make use of citizen engagement in order to increase the service efficiency and coverage. For these reasons, and the engagement of new agents along the service provision chain, we state that the business models of public services implemented in smart cities using smart technologies present significant differences with those conventionally managed (RQ1).

A greater amount of information and the use of big data techniques in order to analyze it enable an increased ability for decision-making and to adjust efficiency in the use of resources. With the exception of the Santander City Brain tool, data are mixed and analyzed with the same platform which allows improving results in the entire value chain. This platform was developed by the University of Cantabria and the Japanese corporation NEC is also developing a more powerful one that will be implemented in the near future. These new approaches require initial investment in technology (sensors, data processing tools, specialized technicians training, etc.). However, those investments are amortized in the long-term, thus saving economic resources for the city council. Although there are expected savings for several services, only the waste management service (a 20% saved with respect to the former contract) and the street lighting service (an expected minimum 65% of the cost) display official figures to support the projections.

The case of Santander is unique within the smart city context regarding the range of research projects being carried in the city around this subject. Some of them have been funded by national and international institutions and have helped to test technologies for the management of urban services before their common adoption. These investments have enabled the development of know-how and the implementation of sensor networks across the city that would not have been possible otherwise within the context of the current economic crisis.

Finally, regarding to cost aspects, we should highlight that citizen engagement through applications allows allocating human resources to other activities.

The main part of the new service's business models rely on the same revenue source than the conventionally managed services, i.e., the municipal budget. However, among the services analyzed in this paper there are some that create new revenue streams. Hence, SantanderRA generates revenue from companies that buy advertising spaces within the application; Santander City Brain have been sponsored by two companies (IBM e ISBAN); and "El pulso de la ciudad" generates revenue enabling online advertising for El Diario Montañés newspaper, the web platform manager. Incomes from funded projects, such as those of European Union Framework Programs add to the revenue models stated above.

The cost reduction arguments described above and the revenue increase lead us to the RQ2: The economic cost of the public services developed by means of ICT is smaller for the citizens than those managed conventionally. Furthermore, we believe that lower service costs should enable future tax reductions or increased spending in other budget expenditures, although, as stated previously, there are not actual data available to support these assumptions as they are currently in the investment in infrastructure stage.

There are further elements within the social benefit parameter that could strengthen the RQ2 answer. Foremost, the deployment of new services with an intensive use of ICT generates around the city a business ecosystem focused in solutions and services for smart cities. Secondly, the creation of new and highly qualified jobs to work for those or other actors of the ecosystem, such as the University of Cantabria or the Santander City Council. These highly qualified workers settle in the city and allow increasing the municipal budget by paying their taxes there. However, as the projects move forward and consolidate, we will need to carry out further analysis in order to state if there is net job creation. Within the literature there is a divergence of views to that respect, some authors consider that the technology development benefits job creation while others think the opposite [90]. And thirdly, it is reasonable to presume that more efficient and of higher quality services will attract more tourists, further increasing revenue this way.

Additionally, the results of our research show that an increased flow of information and a more efficient management of public services enable reductions in energy and water consumption, resulting in an environmental impact reduction (e.g. CO₂ emissions or unnecessary waste of water). Moreover, citizen engagement in projects like Smart Water allows users to contribute to protect the environment enabling them to plan their resource's consumption. Therefore, RQ3 can be addressed stating that municipal services relying on IoT and other smart city's technologies have a reduced ecological footprint.

For various reasons, the ICT based urban service management involves more stakeholders than those public services managed with legacy models. First, the economic crisis avoids public administrations to carry out major investments on their own and many times they rely on public-private partnerships (PPPs). Secondly, the need of expertise in order to carry out some of the most evolved tasks within the system

requires the aggregation of different actors: the University of Cantabria's researchers carry out the IoT infrastructure management and the sensor's data management tasks and additionally they contribute to finding resources as long as they apply for funds to the institutions in order to produce further useful knowledge for the municipal services of Santander; companies as NEC or Ideas4All provide their expertise on some areas of the value chain; El Diario Montañés offers its online content platform, having some of the higher page visits in the region; small businesses help to fund a tourist information application buying geolocated advertising spaces; finally, the City Council takes the role of service administrator, quality controller and a catalyst for all actors. Third, citizens engage actively in the system since they have information to efficiently manage their consumption, and can also, in some cases, produce useful information for the other actors. Addressing RQ4, we state that the use of public services implemented with smart technologies fosters the engagement of different actors in order to achieve sustainable and innovative solutions to socioeconomic and environmental problems.

The stakeholder's ecosystem remains essentially the same; however, the integration of technology opens a new dimension to such stakeholders enabling them to become much more proactive. They do not behave only as consumers but as prosumers which means that, for example, new business models potentially arise. Smart cities are reshaping legacy ecosystems and, as a consequence, bringing new business models.

In addition, the greater participation of companies, entrepreneurs and other stakeholders also boosts the development of the business ecosystem specialized in products and services for smart cities, mentioned above in this section. Participation is encouraged through public speeches for citizens, workshops for entrepreneurs or executives, hackathons, and other activities.

6. Conclusions and limitations

The current research analyses the case study of the business models of Santander's public services in order to identify the most common features of business models in smart cities. The paper is structured around four questions that are answered throughout the research work. A comparison among eight services managed using IoT and other technologies and those implemented before the use of the mentioned technologies shows that their business models have significant differences, even in those cases where the new technologies just complement the conventional management systems.

In order to carry out the analysis mentioned above, we selected the Business Model Canvas for Non-Profits framework, based on the insights collected through in-depth interviews with eleven experts on business model analysis. This management tool has shown to be useful to describe business models in smart cities as it enables to identify important aspects, like social and environmental issues, which other frameworks do not take into account.

Many of the differences among the business models of public services managed conventionally and those managed with innovative technologies are repeated in various cases. The most recurrent differences that the smart public services present are the following: the service maintains the same or superior quality;

there are more actors involved in the management of the service; the total costs are lower in the long term; some initial investment is required; the use of Big Data for decision-making; the users are provided with more information of the service; reductions in energy and/or water consumption are produced; they contribute to foster an ecosystem of IT businesses and professionals in Santander.

The current research allows us to conclude that public services managed with ICT require initial technology investments and know-how; however, they allow the municipality to save costs and to increase management efficiency in the long term. The contract signed with the corresponding company enables the City Council to reduce the cost of the previous contract by 20%. Likewise, the new lighting system is expected to entail a minimum saving of 65% of the previous cost.

The large amount of information is usually managed and analyzed with the same platform, which allows mixing data and obtaining improved results in the entire value chain.

As the current research suggests, smart cities also enable energy and other natural resources consumption savings. Municipal services provided with IoT and other smart city technologies have a reduced ecological footprint when compared with those conventionally managed.

Santander smart city engages different actors in the public services management, more than when the services were conventionally managed. The smart city management benefits from the engagement of citizens that are better informed about the public services and are more committed with their management. Furthermore, the economic crises force local administrations to rely on PPPs projects in order to finance the services. Additionally, the higher complexity of the smart systems requires actors capable of providing expertise. Those factors fully enable the creation of an ecosystem of business specialized in products and services for smart cities and, therefore, new and highly qualified jobs. We have already assessed that the migration towards the smart city paradigm has reshaped the ecosystem built around the city giving much more relevance to the knowledge and technology with the consequent impact in company attraction, start-up creation, etc.

With regard to the limitations of the current research, we should highlight the limited open data available on economic and environmental issues for several of the services analyzed due to their new implementation. Although there is available data for three of the services that support our statements, in the near future we will monitor and analyze new data in order to broaden our research.

Also among the limitations, it has to be said that although the infrastructure has been designed with the aim to cope with some equipment failure, network resilience is one of the key topics to be addressed in the forthcoming phases. Last but not least, data privacy and integrity are also relevant issues which have been taken into consideration when deploying the network [13,91,92].

In our future work we would like to carry out further research on the development of business ecosystems in the smart city and its consequences on net job creation. We will also open a line of research focused on examining citizen perception of the services provided with smart technologies.

We also plan to delve into the development of methods to analyze and benchmark business models in smart cities as we believe that the growth of smart city initiatives will make business model analysis more necessary.

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Highlights**Business model analysis of public services operating in the smart city ecosystem: The case of SmartSantander**

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- This paper studies business models of public services provided with IoT and other technologies in smart cities.
- Eight case studies of technologies implemented in SmartSantander are analyzed.
- Public services properly managed convey cost reductions in the long term.
- There is also a reduction in energy consumption and environmental impact with the consequent social impact.
- Most data are managed with the same platform, improving results in the entire value chain.



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