Financing instruments for Smart City projects based on Internet of Things

Advisor: Prof. Angela Tumino
Co-Advisor: Prof. Giulio Salvatori

Master Graduation Thesis by:
Rafael Alberto ALBOR PALLARES
Student Id. number: 795566

Rina Isabel DE VUONO HERNÁNDEZ
Student Id. number: 795488

Academic year 2014 - 2015
Content

Abstract (in English) .................................................................................................................. 5
  Keywords .............................................................................................................................. 5
Abstract (in Italian)...................................................................................................................... 6
  Parole Chiave ........................................................................................................................ 6
Executive Summary .................................................................................................................... 7
Chapter 1 ................................................................................................................................ 13
  Introduction .......................................................................................................................... 14
  The Internet of Things and the Smart City: A Financing Challenge .................................. 17
    1.1 Internet of Things ......................................................................................................... 17
      Internet of Things (IoT) Background/History ................................................................. 17
      Definitions of the Internet of Things ............................................................................. 19
      Fields of applications of IoT ......................................................................................... 20
    1.2 Smart City .................................................................................................................... 22
      Definitions of Smart City ............................................................................................... 26
      Smart City Dimensions ............................................................................................... 29
    1.3 The Financing Challenge ............................................................................................ 33
    1.4 State of the art .............................................................................................................. 37
      Smart Cities Financing Guide by the Smart Cities Council ............................................ 38
      Smart City: development projects and financing instruments by Cassa depositi e prestiti S.p.A. and the Politecnico di Torino .................................................. 42
Chapter 2 ................................................................................................................................ 47
  Objectives and Methodology .............................................................................................. 47
    General Objective .............................................................................................................. 47
    Specific Objectives .......................................................................................................... 48
    Methodology ..................................................................................................................... 49
Chapter 3 ................................................................................................................................ 51
  Analysis ................................................................................................................................ 51
    Sample of Cities Selected ............................................................................................... 51
    Financing Tools ............................................................................................................... 52
      Public Financing ............................................................................................................ 53
      Private Financing .......................................................................................................... 58
Public-Private Partnership (PPP) Financing .......................................................... 59
General analysis of the aggregated projects ......................................................... 61
Analysis of Smart City Dimensions and Specific Fields ...................................... 64
  Smart Environment ............................................................................................... 65
  Smart Living .......................................................................................................... 71
  Smart Mobility ...................................................................................................... 72
Chapter 4 .................................................................................................................. 79
Conclusion ............................................................................................................... 79
Appendix ................................................................................................................... 84
  Case Study: Smart City Rio de Janeiro ................................................................. 84
  Case Study: Smart City Barcelona ....................................................................... 86
  Case Study: Smart City Boston ............................................................................. 88
Bibliography ............................................................................................................. 91
List of Tables

Table 1. Definitions of Internet of Things ............................................................... 19
Table 2. Definitions of the Smart City concept...................................................... 26
Table 3. Areas of application of the Smart City by Cassa depositi e prestiti .......... 43

List of Graphs

Graph 1. Number of projects analyzed divided into Smart City dimension .......... 62
Graph 2. Percentage of the type of financing implemented amongst all projects .... 63
Graph 3. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Environment dimension ........................................... 65
Graph 4. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Environment Care ........................................... 67
Graph 5. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Lighting ........................................... 67
Graph 6. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Grid .............................................. 69
Graph 7. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Metering ......................................... 70
Graph 8. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Living dimension ...................................................... 72
Graph 9. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Mobility dimension ..................................................... 73
Graph 10. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Parking ........................................... 75
Graph 11. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Traffic ............................................ 76
Graph 12. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Vehicle ............................................. 77
Abstract (in English)

This study is focused on showing the different types of financing tools used to fund Smart City projects that use Internet of Things technologies. For the purpose of this study, many rankings of Smart Cities were researched and a sample of 25 cities was selected to analyze the Smart City projects developed on them. Then a sample of 112 projects that use IoT was selected, from which the financing tools used were analyzed. The projects were divided into 3 Smart City dimensions (Smart Environment, Smart Mobility and Smart Living) and their specific fields according to the characteristics of the projects and the problem they intend to solve. A brief description of many financing tools that are commonly used in this type of projects was provided and then, these tools were aggregated into 3 main financing categories (Public financing, Private financing and Public-Private Partnership) to indicate the source of the financing. Within the category of Public financing projects were subdivided depending on whether they were financed by the City or the National Government (European Union included). Similarly, the Public-Private Partnership category was also subdivided into 3 types of contracts: Management, Operation and Maintenance contracts, Leases and Affermage contracts and Concession and BOT contracts. Finally, an analysis of these financing tools was made for each of the Smart City dimensions and each of their specific fields reaching a conclusion about the results found for each of them.

Keywords: Smart City, Smart City dimensions, Smart Mobility, Smart Environment, Smart Living, Internet of Things, IoT, Financing Tools, Public financing, Private financing, Public-Private Partnerships.
Abstract (in Italiano)

Questa Tesina è focalizzata in mostrare i differenti tipi di strumenti di finanziamento usati per finanziare i progetti di Smat City che utilizzano le tecnologie dell’ Internet of Things (IoT). Ai fini di questo studio, molti ranking delle Smart Cities sono state studiate ed è stato selezionato un campione di 25 città per analizzare i progetti sviluppati in ognuna. Dopo, un campione di 112 progetti che utilizzano IoT è stato selezionato, dei quali gli stumenti di finanziamento utilizzati sono stati analizzati. I progetti sono stati divisi in 3 dimensioni della Smart City (Smart Environment, Smart Mobility and Smart Living) e in suoi campi specifici in funzione delle caratteristiche dei progetti e il problema che intendono soluzionare. Una breve descrizione di molti strumenti di finanziamento che vengono comunemente utilizzati in questo tipo di progetti è stato fornito e poi, questi strumenti sono stati aggregati in 3 categorie principali di finanziamento (finanziamento Pubblico, finanziamento Privato e Partenariato Pubblico-Privato) per indicare la fonte di finanziamento. All’interno della categoria di finanziamento Pubblico i progetti sono stati suddivisi dipendendo di se sono stati finanziati dalla città o dal governo nazionale (Unione Europea compresa). Allo stesso modo, la categoria di Partenariato Pubblico-Privato è stata suddivisa in 3 tipi di contratti: Management, Operation and Maintenance contracts, Leases and Affermage contracts and Concession and BOT contracts. Finalmente, un’analisi di questi strumenti di finanziamento è stato fatto per ciascuna delle dimensione della Smart City e ciascuno dei suoi campi specifici raggiungendo una conclusione su i risultati trovati per ciascuno di essi.

Parole Chiave: Smart City, dimensione della Smart City, Smart Mobility, Smart Environment, Smart Living, Internet of Things, IoT, strumenti di finanziamento, finanziamento Pubblico, finanziamento Privato, Partenariato Pubblico-Privato
Executive Summary

Today the world is facing a reality in which resources, such as fuel, energy and water, are reaching their limits and humanity has created more problems that it can currently solve. Taking into account that cities cause approximately 70% of the greenhouse emissions (Fong & et al., 2012) that pollutes our world and consume up to 75% of the global energy, it can be said that the origin of most of the current problems can be pin-pointed to cities, transforming them into places where chaos, congestion and inconformity linger. On top of this, it can be expected that these problems will get worse if nothing is done to correct them, due to the increase of the global population in urban settings, which is expected to reach more than 70% of the total world population in 2050, according to the World Health Organization. In order to prevent this, many cities are acting intensively to better manage their resources, their capacity and become more responsive to change, and thus, achieve sustainability, throughout the use of new technologies. This new approach consists of transforming the cities into Smart Cities with the collaboration of the cities’ governments, technology companies, universities, research institutions, and the citizens in them.

Currently some cities around the world have grasped the massive potential that these new technologies can have in improving their systems and services. The idea is that these cities use Information and Communication Technologies (ICTs) to address, in an efficient and effective way, problems such as mobility, traffic control, security, energy and waste management, which are the most common to arise when the population in a city grows. Taking into account that most of these problematics can be better managed if city leaders can have access to the right information to make better decisions, and for this to happen the ICTs can be reliable allies; especially the Internet of Things (IoT) technologies that have been gaining a lot of interest in the last decade and that can be implemented as tools to reach the future vision of the Smart City.

There are many definitions about the concept of the Internet of Things, which have been evolving through the years. All of them arrive at a common point and it is that any object or thing can be connected to the internet, increasing their value, becoming Smart Objects; some of them just providing information and some even taking actions without any human interaction according to the data collected. In other words, IoT, also known as Internet of Everything (IoE) and ubiquitous network, not only allows transportation of data and
communication between different people, characteristics of the first stages of the Internet, but also allows interaction with and between things, at anytime and anywhere.

The technologies of the Internet of Things are being used in different fields of applications, so far divided in 11 fields explained in the study, each focusing in different aspects to improve the day-to-day life of people. One of these fields that has been gaining a lot of interest among governments, technology companies, academic institutions and people in general, is the one related to the Smart City that opens up a world of possibilities in which people are able to control some features of their houses, search for parking spots, a place to eat or just catch a bus in time, without wasting time waiting.

The Smart City concept currently does not have a standard definition accepted by scholars and organizations worldwide, but in recent years the term has begun to convey to a more common consensus. Taking into account the point of view of technology companies, cities' governments and scholars, the definition of Smart City used in the present study is as follows:

“To be considered a Smart City, a city must develop initiatives and programs directed to improve the sustainability, economic growth and quality of life of the citizens, through the implementation of ICTs and technologic advances. With the purpose of enhancing the services and infrastructure of the city, in one or more dimensions (Smart Governance, Smart People, Smart Environment, Smart Living, Smart Mobility and Smart Economy), guided by the government, supported by the private sector and academic organizations, in terms of investment and technologic developments, and with the active involvement of the citizens in the process”.

One of the challenges related to the creation of the Smart City initiatives and projects, is that they are expensive and a lot of the technology used in these kinds of projects is relatively new, increasing the financial risk that Smart City projects have associated to them due to the uncertainty of the success or impact of the new technology, making a main obstacle finding the resources necessary to develop, test and launch these technologies. But regardless of this, currently governments, technology companies and private investors, among others, are showing increasing interest in developing and financing this type of projects, due to the impact they can have on cities in terms of environmental sustainability, economic competitiveness and improvement in the quality of
life of its citizens. When evaluating which type of financing to select for any kind of project, decision makers must have in mind that different types of projects in each city can demand different types of financing, that’s why in the evaluation process having the right amount of information is essential to make the “correct” decision.

Out of the 25 cities selected as best practices in the Smart City paradigm, spread in Europe, Asia, and North and South America, 112 projects were selected and thoroughly analyzed to validate them as candidates to the present study, based on the fact that the projects used Internet of Things technology, were focused in developments or improvements related to the Smart City paradigm and that the information of the financing of the projects was available.

The Smart City paradigm was divided in 6 dimensions named Smart Society, Smart Government, Smart Economy, Smart Environment, Smart Mobility and Smart Living, to better categorize the projects and initiatives made in the cities and transform them into Smart Cities. The projects analyzed in the present study belong only to 3 of the 6 Smart City dimensions, because only in the dimensions of Smart Environment, Smart Mobility and Smart Living were found projects that implemented IoT technologies, which are the focus of this study. Regarding the other 3 dimensions (Smart Society, Smart Government and Smart Economy), although they are important to develop a Smart City and there are multiple projects that belong to these dimensions, in the present time the projects related to them are not implementing Internet of Things technologies to function, which leave them out of the present study. From the 3 dimensions analyzed, Smart Environment and Smart Mobility have the largest amount of projects, due to the fact that most cities nowadays have as a priority solving the problems related to the Climate Change phenomenon, thus improving the public transportation systems, the traffic, the energy grid and the public lighting, among others, are top priority in the objectives of the city in the near future.

Many financing tools were explained in the study and then they were aggregated into 3 financing categories depending on the source of financing for any kind of project – Public financing (City or National Financing), Private financing and Public-Private-Partnerships (Management, Operation and Maintenance contracts - Lease and Affermage contracts - Concessions and BOT contracts). Only the categories of Public and PPP financing were further subdivided into financing tools according to the information gathered to have a better understanding of the behavior of the investors of these projects. The private financing category was not subdivided due to the fact that the projects analyzed and
placed in this category are business projects and the information about the source of the investment is not public.

The most common financing group for the Smart City projects analyzed without taking into account the dimension of origin is the PPP, from which Leases and Affermage contracts are the most common, followed by the use of Public financing, which, according to our findings, do not show a notable difference between the amount of projects financed solely by cities and the ones receiving financing from national government, showing the commitment that the Public sector has with the Smart City movement. This is due to the fact that the Public sector is more willing to take on the financial risk of the uncertainty of the projects for the benefit of its citizens. On the other hand, although the quantity of projects financed through Private financing is rather low in comparison with the other two types of financing, the presence of these projects shows an increasing attention from the private sector into the Smart City paradigm, even though the high financial risk of them cause the private sector to be cautious when investing in this sector.

Regarding the process of how the financing used in the projects were analyzed, an analysis of each dimension and their specific fields was made. The Smart Environment dimension contains the following specific fields:

- Environment Care
- Smart Lighting
- Smart Grid
- Smart Metering

It was found that there are a total of 53 projects in the Smart Environment dimension. The predominant type of financing in this dimension was the PPP, almost doubling the amount of projects held in the Public financing category. This dimension reflects the distribution for the entire sample of projects, in which PPPs are the most common financing group (57% of the projects in the dimension), followed by Public Financing (32%) and at last Private financing used by only 11% of the projects in the dimension. Another similarity is that Leases and Affermage contracts are the most common type of PPP used in the dimension, followed by Concessions and BOT contracts. The specific fields in this dimension follow a similar distribution in terms of the 3 main financing groups but have
differences in terms of the specific financing tools used in them, in which depending on the scale of the projects and the complexity of the technology used, different types of PPPs and Public Financing are used for each of the specific fields.

The Smart Living dimension holds the smallest amount of projects within the entire sample with only 8 projects, and all these projects were aggregated at the dimension level and not in specific fields, due to the low quantity of them. The financing for this type of projects follows the general distribution, being the PPPs the most common method for financing the projects and the private financing the less used, with the difference that in this case the Concession and BOT contracts are the most used financing tool within the PPPs, followed by a tie between the other two PPP financing tools. An interesting fact about this dimension is that all the projects financed by the public sector were financed by the National Government instead of the city, once again showing that cities are focused in developing projects for the Smart Environment and Smart Mobility dimensions.

Regarding the Smart Mobility dimension, a total of 51 projects was found and aggregated in 3 specific fields:

- Smart Parking
- Smart Traffic
- Smart Vehicles

The large amount of projects found for this dimension was expected, taking into account that the increase in traffic congestion and the pollution caused from it is one of the major problems in most cities around the world and the majority of them are searching alternative methods in the transportation system to solve these problems. The financing of the projects in this dimension deviates from the general distribution showed by the whole sample, due to the fact that the financing was made in 50% of the cases by the public sector, especially by the national government, and that although the private sector only financed 18% of the projects in its category by itself, this percentage is higher than in the other dimensions. This behavior shows that both private and public sector are more confident in financing projects in the Smart Mobility dimension by themselves than in the other Smart City dimensions and this causes that there is a rather small amount of projects that were financed by PPPs (32% of the projects in the dimension). In the PPP financing group, Leases and Affermage contracts were the most common financing tool used in the
projects, accounting for 16% of the projects in this dimension and both Management, Operation and Maintenance contracts and Concession and BOT contracts account for 8% of the projects each. The high amount of projects financed by the public sector shows the importance that the government gives to Smart Mobility and that it is a priority for them to invest in it to reduce the CO2 emissions caused by poor traffic control. This is caused by the fact that public transportation is one of the main services provided for the citizens by the city and its leaders must be sure not to give too much power to the private sector to avoid negative repercussions caused by the changes made to improve the traffic in the city.
Chapter 1

The main objective of this chapter is to collect information in a systematic manner about the Smart City concept and its fields of application, the evolution of the Internet of Things and its implementation in Smart City projects and lastly, the financing instruments available in this market for the development of these projects, to have a frame of reference for the present study. Furthermore, it will be presented the state of the art related to the financial guides created to help developers, entrepreneurs and city leaders to find financing for their Smart City projects focused on the projects that applied Internet of Things technologies.

Outline

1. It will be explained the evolution in technology which led to the creation of the Internet of Things (IoT) and its relationship with the Smart City.

2. A view of the events and problematics which led to the development of the idea of the Smart City will be presented, followed by a description of the evolution of the Smart City concepts through time.

3. The main types of financing methods will be defined and explained.

4. Then, an analysis and summary of the state of the art in financing guides for Smart Cities will be shown.
Introduction

“The 19th century was a century of empires, the 20th century was a century of nation states and the 21st century will be a century of cities” Former Denver Mayor W. Webb

Today, the world is facing a reality in which resources, such as fuel, energy and water, are reaching their limits and humanity has created more problems that it can currently solve. Cities are one of the biggest issues, causing approximately 70% of the greenhouse emissions (Fong & et al., 2012) that pollutes our world and, due to the increase of the global population in urban settings; cities are becoming places where chaos, congestion and inconformity linger. The problem is doomed to get worse if nothing changes and that might be the case according to the World Health Organization, which expects a growth of 1.84% per year of the global urban population between the years 2015 and 2020. In order to prevent this, many cities are acting in a proactive manner to better manage its resources, its capacity and become more responsive to change, and thus, achieve sustainability, throughout the use of new technologies.

As a way to responding to the ever changing urban scenario, all around the world there is an increasing interest in the Smart City idea. Some people believe in it like the magical solution that humanity needs and has been waiting for; others believe that governments and business interests with their everlasting marketing campaigns are trying to sell us a marvelous world that is far from being achieved. However, even though it is true that in the beginning and for several years after, the realization of the Smart City idea was initially promoted by technology companies, like IBM and Cisco, mainly to create market for their products, currently some cities around the world have grasped the massive potential that these technologies can have in improving the system of the city and modernize how a city serves its citizens. Additionally, no one can deny that in the last decades the evolution of technology has provided many tools to improve the sustainability and quality of life in cities and thus, city leaders and communities are focusing their efforts in developing and implementing them, with the purpose of transforming the current cities in Smart Cities. The idea is that these cities will use Information and Communication Technologies (ICTs) to address, in an efficient and effective way, problems such as mobility, traffic control, security, energy and waste management, which are the most common to arise when the population in a city grows.
Most of these problematics can be better managed if city leaders can have access to the right information to make the correct decisions, and for this scope the Information and Communication Technologies (ICTs) can be reliable allies.

In general, is well known that the best pathway to solve any problem or to prevent one is to gather information about its characteristics and the possible causes creating it, analyze this information, propose ways of solving or preventing it, and finally selecting the best option according to the information available. The same process works for the problems cities are facing nowadays. Consequently, one of the key factors to solve them is to obtain information about the elements of the city that are causing the problems. However, just until a few years ago, the collection of data regarding these elements was time-consuming and often, due to the changing dynamics of the cities, the information taken from this data was obsolete or it served to solve the problems, but not to prevent them. In the present, thanks to the evolution technology has experienced in the last decades, it is possible to gather a vast amount of information in real time, from different sources, with the purpose of being shared through the internet with interested parties as raw data collected or as information that has been aggregated or analyzed, in order to be able to predict future problems related to the city and perform actions to prevent them.

Within the Information and Communication Technologies (ICTs), a type of technology that have been gaining a lot of interest in the last decade is known as the Internet of Things (IoT), which uses different types of technologies, for example Radio-Frequency Identification (RFID), Near Field Communication (NFC), GPS tracking devices, that can be implemented to reach the future vision of the Smart City. But then again creating, refining and using new kinds of technologies is not only difficult for the fact that great innovation and vision is needed, but in reality, one of the main obstacles in the evolution of new technologies, isn’t related to technical aspect, but is to find the resources necessary to develop them, test them and launch them. Basically, this obstacle is financing, a key factor for the success of any project, especially those related with development of new technologies, because of the high financial risk that this kind of projects have associated to them due to the uncertainty of the success or impact of the new technology.

In response of the many Smart City initiatives developed around the world associated to the issues caused by the growing population in urban settings, city’s tight budgets and the scarcity of resources, the problem of financing is constantly been acknowledged by more and more people and diverse ways of financing these initiatives have been emerging
throughout the world. Currently, governments, technology companies and private investors, among others, are showing increasing interest in developing and financing this type of projects, due to the impact they can have on cities in terms of sustainability, competitiveness, economic growth and improvement in the quality of life of its citizens. Essentially, most governments want to invest in increasing the attractiveness, competitiveness and most importantly the sustainability of their cities. On the other hand, the private sector is usually looking for lucrative projects, which in the case of IoT is possible, but risky, because of the uncertainty new technology carries with it. Unfortunately, the private sector, who due to the risk in these projects is less likely to invest, is the one with more capital available for these technological innovations. Thus, it is crucial that this sector becomes an important part of the Smart City and IoT world in order to push it forwards and make it a reality. Lately there has been more involvement of the private sector in IoT innovation and cities are creating partnerships with private companies to finance and support Smart City projects. Although it is not yet spread throughout the world, this trend could lead to the future of Smart Cities.
The Internet of Things and the Smart City: A Financing Challenge

The concepts of Smart City and Internet of Things (IoT) are relatively new and it is crucial to understand them before doing an analysis on a subject related to them, in this case, financing. Due to this, it is important to have a grasp of these concepts, their definitions and scope, which is why a research about them has been done. The concept of financing will also be described in this chapter. Despite being analyzed separately, these 3 concepts are highly interconnected and the product of this relationship is the very essence of this thesis.

1.1 Internet of Things

Internet of Things (IoT) Background/History

“The history of technological progress is punctuated by game-changing advances many of which have unobtrusively integrated themselves into the fabric of modern life”. (Prabhu, 2013)

Technology, like many other streams of knowledge before it, has become an essential part of our societies, allowing us to improve, imagine and create, better and new kinds of ways to live. One type of technology, which is now considered a game-changing advance, is the Internet. Since its inception, in 1971, has been evolving non-stop and has proven to have huge potential to change the way humanity had live up to this point. From its original academic network approach in the 1980s to a consumer-oriented network in the 1990s, thanks to the development of the World Wide Web in 1989, the Internet has always being evolving. Conceived, from the very beginnings as a global network to exchange information and digital content without restrictions of time or distance (Universidad de Deusto, 2011), the Internet generated significant progresses in the condition we worked and lived. But, as expressed by Cisco CEO John Chambers and Executive Vice President Wim Elfrink, in Foreign Affairs: “as much as the Internet has already changed the world, it is the Web’s next phase that will bring the biggest opportunities, revolutionizing the way we
live, work, play, and learn. That next phase, which some call the Internet of Things and which we call the Internet of Everything, is the intelligent connection of people, processes, data, and things”.

The Internet of Things (IoT), also known as Internet of Everything (IoE) and ubiquitous network, not only allows transportation of data and communication between different people, characteristics of the first stages of the internet, but also allows interaction with and between things, at anytime and anywhere, and this will cause another change in the way our society works and in how we see the world.

At present and for almost half a century, the Internet, computers and diverse electronic devices have become part of our daily life. Today, according to Cisco, 50% of the world’s population is hooked up to the internet via computers or mobile devices to do everything, from keeping in touch with friends, work, to even paying bills, and by 2020 this number is expected to rise to 66%. In fact, the number of things, from electronic devices to traditional objects, which are connected to network services, has increased dramatically in recent years, being higher than the number of people. The number of devices connected to the internet at present, is approximately 13.5 billion devices and Cisco expects that this number will increase to 50 billion by 2020, taking into account that these devices comprise traditional ones, like computers, cellphones or tablets, but in the last 5 years and in the future, also everyday objects will be connected, collecting, processing and sharing information, like parking spaces, garbage cans, streetlights, water irrigation systems, buses, alarm clocks and so on.

Even though the concept of “Internet of Things” was first expressed as “computers everywhere” by professor Ken Sakamura in 1984, followed by Mark Weiser in 1988 as “ubiquitous computing”, it was only until 1998 that, Kevin Ashton named the concept as we know it today, the “Internet of Things” (IoT) describing it as “a standardized way for computers to understand the real world”. A few years later, in 2003, in the Auto-ID Center of MIT began the development of the IoT concept, with the creation of the RFID tag, followed by multiple initiatives by the private sector, from companies like Intel, IBM and Cisco, and nations such as the United States, European countries, Japan, China and South Korea. Although, more than 15 years have passed, Ashton’s vision is still applicable to the concept of Internet of Things, and although nowadays, there are many interpretations of this concept, all of them arrive at a single common point and it is that any
object or thing can be connected to the internet, some of them just providing information and some even taking actions without any human interaction, according to the data collected. In order to have a clearer idea of the meaning of the Internet of Things, in Table 1, there is a compilation of some of the definitions available in recent years of the concept of Internet of Things. Recent definitions tend to focus in one of the two key elements of Internet of Things; the first is the objects or things and their increase in value by being connected to the internet and the second element is the network which will connect all of them, allowing the information sharing, creating a systems of systems, which some companies such as Cisco, believe is the most important part of the Internet of Things.

**Definitions of the Internet of Things**

<table>
<thead>
<tr>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chad Jones (2013)</td>
<td>The next great paradigm shift in the Internet will be the inclusion of the Internet INSIDE of everything we see in the physical world. Described as The Internet of Things (IoT), the Internet of Everything and the Industrial Internet, it promises to revolutionize not only how we discover, interact and understand our world, but the way we experience our everyday private and working lives. This evolution in technology has captured the imaginations of education, government and businesses alike.</td>
</tr>
<tr>
<td>IEEE (2014)</td>
<td>Internet-of-Things (IoT) is the convergence of Internet with RFID, Sensor and smart objects. IoT can be defined as “things belonging to the Internet” to supply and access all of real-world information.</td>
</tr>
<tr>
<td>Intel (2014)</td>
<td>The Internet of Things (IoT) is an evolution of mobile, home, and embedded devices that are connected to the internet, integrating computing capabilities and using data analytics to extract valuable information. Soon, hundreds of billions of devices will be connected to the Internet. Connected devices become intelligent systems of systems, sharing data over the cloud and transforming our businesses, lives, and world in countless ways.</td>
</tr>
<tr>
<td>Cisco (2014)</td>
<td>Internet of Everything (IoE) as bringing together people, process, data, and things to make networked connections more relevant and valuable than ever before—turning information into actions that create new capabilities, richer experiences, and unprecedented economic opportunity for businesses, individuals, and countries.</td>
</tr>
</tbody>
</table>

Table 1. Definitions of Internet of Things
The Internet of Everything is already revolutionizing the way our cities operate, creating a more dynamic global economy and also bringing new, richer experiences to citizens. Soon, we will live in a world where everything — and everyone — can be connected to everything else. [...] The Internet of Everything will change how we work — more information, better decisions, more agile supply chains, more responsive manufacturing, and increased economic value. The foundation of the city of the future will be the Internet of Everything, and those embracing this technology are leading the way.

The interconnection via the internet of computing devices embedded in everyday objects enabling them to send and receive data

Accenture (2015)
The Industrial Internet of Things (IIoT) is a network of physical objects, systems platforms and applications that contain embedded technology to communicate and share intelligence with each other, the external environment and with people. The adoption of the IoT is being enabled by the improved availability and affordability of sensors, processors and other technologies that have helped facilitate capture of and access to real-time information.

Kevin Ashton (2015)
The internet of things is really adding two components to computers as we understand them today. One is sensors, the ability of the computer to understand the world by itself. The other is networking, the way those sensors can be distributed all over the place, they can be gathering different kinds of information in different locations, thus stream to the computer who suddenly understands the world.

### Fields of applications of IoT

Now that it was given a frame of reference to the paradigm of the Internet of Things, a brief description of its current fields of application will be given, according to the report “Internet of Things: Smart Present or Smart Future?” of the “Osservatorio Internet of Things” of the Politecnico di Milano.

**Smart City:** IoT tools related to the management and control of the elements within a city, such as public transportation, city lighting, parking and waste management, among others.
As mentioned before, the connection between IoT and the Smart City is the core of this thesis, so this field of application will be expanded in Section 1.2.

**Smart Environment:** IoT tools to monitor natural environments such as forests, rivers, and mountains to make and keep them sustainable and to prevent catastrophes or accidents.

**Smart Metering and Smart Grid:** Smart Metering to get real-time information about the consumption of the basic services in a city (electricity, water, gas, heating), and Smart Grid to optimize the distribution of electricity in the city.

**Smart Home:** It refers to the improvement of the everyday items in a home, such as the control of lighting, electrodomestics, heating and security to provide a better environment for the people in it and to even reduce the consumption of utilities.

**Smart Building:** Automatic management of the equipment and systems in the building (lighting and ACHV), especially those related to energy saving and security of the people inside.

**e-Health:** IoT technologies for the real time monitoring of the vital signs of the people, like blood pressure, heartbeat and level of sugar in the blood, to provide more precise information for doctors, hospitals and patients and thus, improve the lifestyle of the patients.

**Smart Car:** Connection between a car and others or the surrounding infrastructure, to prevent and notify about accidents, to provide new insurance models and/or information on road conditions and traffic, related to the current position of the car.

**Smart Logistics:** Solutions related to the traceability of merchandise, its security and the conditions in which it is (really important in the sector of cold food or for some medication), providing brand protection and recognition.

**Smart Asset Management:** Management of valuable assets remotely, to provide information about its condition and location, allowing a better control of the maintenance, repairs, traceability and inventory management.
Smart Factory: Aimed at production management, in which IoT tools are used to gather real time information of the process of a machine and by the use of algorithms allow the communication between other machines in the process.

Smart Agriculture: IoT tools that allow tracking microclimate parameters to support agriculture techniques to improve the quality of products reduce the resources used and the environmental impact.

The Internet of Things, a concept that no so far ago seemed like something taken from a science fiction novel, is becoming a reality for businesses, governments, and academic institutions all around the world. This new evolution of the internet opens up a world of infinite possibilities in which people are able to control some features of their houses, search for parking spots, a place to eat or just catch a bus in time, without wasting time waiting. A world in which governments can have more information, through sensors and other devices, regarding the daily function of the city, like traffic flow, energy use (Smart grid) and waste recollection amounts, making the management of the city more easy and improving the services giving to the citizen, in other words, helping the city become a Smart City.

1.2 Smart City

“These cities that are doing the best at embracing the future are focusing on improving technology, equality, sharing, civic participation, and more” (Cohen, The Smartest Cities In The World, 2014).

The Smart City seeks to find new methods and solutions in order to overcome the challenges and problems that the increasing density of the population within cities is causing. The path to achieving this is by finding ways to better manage the city’s resources and be able to satisfy the needs of citizens, offering enhanced services and looking to cut waste through the city’s system, in order to become a Sustainable City, a place that can offer a suitable place for citizens to live, in a planet that seems to be too small for what is coming. It is appropriate to notice that being a Sustainable City is not considered as the same thing as being a Smart City. The main difference between these
two terms is that the later uses Information and Communication Technologies (ICTs) to achieve sustainability (Mortensen & et al., 2013) and thus, it is more likely to reach this goal in a faster way and with a smaller economic impact, due to the fact that Smart Cities can count with more information, recollected through sensors, CCTV and other devices, allowing an improved understanding of the city and citizen needs and therefore, leading to do a better decision and policy making, consenting an enhanced management of the available resources and cutting waste to create a better quality of life.

With these ideas in mind, most governments worldwide are showing concern about the growing population in their cities caused by the exponential increase in the migration of people to urban centers in search for employment, better job opportunities or simply to improve their lifestyle. In fact, according to the United Nations more than 50% of the population in 2014 lived in urban centers and by 2050 it is expected to increase to 70%, showing that the expected trend is on the rise unless some changes are made to slow it down or stop it. Despite the excessive amount of people is a concern, it is not the problem that society is facing today, but its cause. The real problem of this phenomenon is that it brings challenges to cities in terms of water and solid-waste management, transportation methods, congestion, traffic, falling budgets, energy supply, pollution, crime, aging infrastructures, availability of residential areas, commercial zones, and office and public spaces, among others, evidencing that the current management system and policy making of cities are obsolete. It is for these main reasons and some more, that today the Smart City vision has captured the attention of so many people and governments in search of tools that help them achieve the solutions that humanity needs, in order to be able to amend for the errors that it has made in the past and to ensure a better future for the present and next generations.

Currently, cities and governments also face challenges related to budget availability for new investments in the city’s infrastructure; they are fighting with diminishing resources and climbing costs, looking for methods to help them save funds or for financing tools to support the development of the needed infrastructure’s updates. One way of overcoming these budget limitations is through the implementation of a strategic urban planning that involves the use of ICTs and Internet of Things to update the current systems and thus, reduce costs caused by the misuse of the infrastructure and use efficiently the resources at hand.
At present, the city’s infrastructure has many parts that are obsolete and incur high installation and maintenance costs. In fact, the single largest budget item for many cities around the world is the solid-waste management item, which generally is higher in countries with higher economic development and rate of urbanization (World Bank, 2012), which means that with the increase in urban population this item is bound to rise. According to predictions made by the World Bank, cities around the world generated in 2012 approximately 1.3 billion tons of solid waste per year, which amounts costs of $205.4 billion annually, and the expectations are that by 2025 this volume will reach 2.2 billion tons per year, translating in costs of $375.5 billion annually. With today’s garbage recollection fixed-route system and these gloomy predictions, it is imperative to find ways to better manage and reduce these costs and luckily, a technological solution, based on the Internet of Things is available, consisting in the incorporation of sensors in residential and commercial solid-waste containers, which alert the city waste management system when the container is full, optimizing the recollection routes of the garbage trucks, causing an increase in efficiencies and workers productivity, and reducing costs and pollution simultaneously, contributing to the sustainability of the city.

According to the United Nations Human Settlements Programme (UN-Habitat), another one of the biggest municipal budget items in many parts of the world is the cost related to energy. They also argue that cities need to become more energy efficient and strike a balance between three fundamental goals: quality of life, economic competitiveness and environmental protection to create well-functioning cities, goals that are in sync with the Smart City purpose. These energy-related costs can be reduced, for example, by simply embedding Internet of Things technology, like sensors in the street lighting systems, which can account for up to 40% of any municipality’s electrical bill worldwide, according to Navigant Research. These sensors can have many functions, like deem the light according to the environment’s amount of light, turning on the street lights if someone is approaching it or turning it off if none is around, and sending reports of the state of the bulbs and the system in general to the control room of the electricity company, among other features that can be provided by adding other kind of sensors to the structure of the street light. With the use of networked motion-detection lights, cities can have savings of 70% to 80% on electricity use and costs related with the daily functions of the street lights, according to an independent, global trial of LED Technology, and contributing to improve the quality of the environment and life in the city, potentially reducing crime since the Smart street lighting consents a better visibility, according to Cisco. A more complex but
effective approach that can help reduce the energy-related costs is by opting to change the electric grid from a traditional grid to a Smart Grid and installing Smart Metering in the public, residential and commercial buildings in the city. These changes could not only save a significant amount of money to the city and its citizens, but also favor the city’s competitiveness and make it more sustainable.

Other similar problems are due to the old pipes that comprise the water systems and the old sewage systems in many of the world’s cities, some of them are in need of a prompt replacement. The restructuration or replacement of these old systems costs over the years a significant amount of money, but taking into consideration that these works must be done and the budget for these must be spent, these systems can be improved at the same time that the upgrading is occurring. For the water system, the improvement can be done by simply adding networked sensors in water mains and pipes systems and for the sewer system, by incorporating sensors to monitor the water and bacterial level in the sewers, with the purpose of having a better monitoring of the systems in the future, allowing the anticipation of leaks, overflows and future potential problems, using more effectively the resources available today and helping to save funds and improving the environment in the future. These and more cities’ problems, like traffic congestion and parks’ irrigations systems, can find solutions or at least ways to improve the situations, through the use of Internet of Things technology, as proven by many successful initiatives in motion around the world.

The importance of the Smart City for the future of humanity is very clear, and the ways to begin the road to become a Smart City are usually clear too (depending on the city’s main problems) but what is unclear at the moment is the very concept of Smart City. Although in recent years the term has begun to convey to a more common consensus, there is not a standard definition accepted by scholars and organizations worldwide yet. It is clear the difference between Smart City and Sustainable City, but the concept of Smart City is still ambiguous. From our research it can be comprehended that the definition for a Smart City can vary depending on the scope that the regions, companies or organizations give to it. Because of this, a select recollection, according to the scope of this study, of some of the definitions available for Smart City throughout the years are shown below, in Table 2, in order to analyze and understand them and have a robust idea of the meaning a Smart City has today.
### Definitions of Smart City

<table>
<thead>
<tr>
<th>Source</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Caragliu, Del Bo, &amp; Nijkamp, 2011)</td>
<td>We believe a city to be smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance.</td>
</tr>
<tr>
<td>(Smart Cities Council, 2012)</td>
<td>A smart city is one that has digital technology embedded across all city functions. It is one that gathers data from smart devices and sensors embedded in its roadways, power grids, buildings and other assets. It shares that data via a smart communications system that is typically a combination of wired and wireless. It then uses smart software to create valuable information and digitally enhanced services.</td>
</tr>
<tr>
<td>(Vaquerizo, 2012)</td>
<td>Interview to Pilar Conesa, Director of “Congreso Mundial Smart City de Barcelona”: The Smart City is the new paradigm, in which the diverse initiatives linked to environmental sustainability, economic sustainability and from the point of view of the improvement of the quality of life of the citizens are highlighted.</td>
</tr>
<tr>
<td>(Manville &amp; et al., 2014)</td>
<td>A Smart City is a city seeking to address public issues via ICT-based solutions on the basis of a multi-stakeholder, municipally based partnership. To be classified as a Smart City, a city must contain at least one initiative that addresses one or more of the following characteristics: Smart Governance, Smart People, Smart Living, Smart Mobility, Smart Economy and Smart Environment.</td>
</tr>
<tr>
<td>(Cohen, The Smartest Cities In The World, 2014)</td>
<td>Over the past several years, the idea of the being “Smart” has emerged as a key mechanism for cities to find innovative solutions to the challenges that they are facing. A city is more or less “Smart” than another city according to the amount of development in each of the six key components of a Smart City, which are: Smart Environment, Smart Mobility, Smart Government, Smart Economy, Smart People and Smart Living.</td>
</tr>
<tr>
<td>(Radhesh, What it takes to be a Smart City? (Part 1), 2015)</td>
<td>Smart City uses technology to enhance quality, wellbeing and safety of citizens. It provides means to engage more effectively and actively with its citizens and enterprises. And lastly, it helps city authorities to reduce costs and resource consumption for their cities.</td>
</tr>
</tbody>
</table>

Table 2. Definitions of the Smart City concept.
A smart city brings together technology, government and society to enable the following characteristics: a smart economy, smart mobility, a smart environment, smart people, smart living and smart governance. We believe "Smart Cities" includes such things as: Smart Buildings, Smart Living, Smart Transportation, Smart Energy, Smart Communications, Smart Networks, A Self-Aware Digital Hub and Environmental Awareness (i.e. changing weather conditions; human defined changes).

Smart cities are a new style of city providing sustainable growth and designed to encourage healthy economic activities that reduce the burden on the environment while improving the QoL (Quality of Life) of their residents. Smart cities are not something that should be tackled by just governments and corporations and then presented to residents. The general public must also be actively involved in sharing their own ideas and helping to formulate the cities by throwing their own wisdom into the pot. That is what smart cities are all about.

It’s a new concept defining a city that works to improve the quality of life of all its citizens, meeting their needs, and ensuring a sustainable, social, economic and urban development. A Smart City is based on the use and modernization of new information and communication technologies (ICT) in order to provide a more efficient management of the city’s services and resources. It is a city that facilitates the interaction of its citizens with its administration. A place that supports and fosters personal and business development and where open information is available in real time. Finally, a city that wishes to aspire to being a truly Smart city must develop all of its key areas (transport, energy, education, health, waste management, security, economy…) simultaneously and transversally.

In spite of the fact that there are still different, but similar definitions of Smart City in use currently, it is easy to understand from these ones, that the creation of Smart Cities should become a priority, at least for the next 15 years, in government’s action plans and in technology companies’ new business strategies, in view of the benefits that the creation of these cities will bring not only to humanity but also to the restoration of the natural environment.
In reference to the definitions of a Smart City shown in Table 2, there are two common points found in these ones. The first point involves the *use of ICTs and technologic advances to achieve economic and environmental sustainability and to improve the quality of life of the citizens*. The second one consists of the *involvement of the government and its citizens, and the support of the private sector* in the development of the initiatives towards the creation of a Smart City. Taking into account the point of view of both technology companies, cities’ governments and scholars, the definition of Smart City used in the analysis of this thesis is:

“To be considered a Smart City, a city must develop initiatives and programs directed to *improve the sustainability, economic growth and quality of life of the citizens*, through the *implementation of ICTs and technologic advances*. With the purpose of *enhancing the services and infrastructure of the city*, in one or more dimensions (Smart Governance, Smart People, Smart Environment, Smart Living, Smart Mobility and Smart Economy), *guided by the government, supported by the private sector and academic organizations*, in terms of investment and technologic developments, and with the *active involvement of the citizens in the process*”.

In the last couple of years there has been an interest in classifying the Smart City initiatives into smaller fields of application, each one tackling a different aspect of the city, as can be seen in the definitions of the (Manville & et al., 2014), (Cohen, The Smartest Cities In The World, 2014), and (Institute of Electrical and Electronics Engineers (IEEE), 2015) shown in Table 2. This classification has led to 6 key dimensions of a Smart City, which are: *Smart Governance, Smart People, Smart Environment, Smart Living, Smart Mobility and Smart Economy*, also mentioned in the Smart City definition for this thesis.

Each of these dimensions will be described below, primarily based on information gathered from the study “Mapping Smart Cities in the EU” by Manville & et al, and the report “The Smartest Cities in the World” by Boyd Cohen Ph.D.
Smart City Dimensions

Smart People

“Cities without people aren’t cities at all. That’s why a truly smart and connected city begins with people who are smart and connected” (Vander Veen, 2015).

As implied by its name, the Smart People dimension covers the access that people in the community have to Internet services, to education and training in technological fields and to the e-skills that the population have, within an inclusive society that improves creativity and fosters innovation. Another important factor is that it enables citizens to have access, edit and manage data, through analytics tools and dashboards, to have more tools and information at their disposal in order to make better decisions.

The Smart People dimension is a basic and important part of creating a Smart City, because it serves no purpose to have an intelligent infrastructure if people aren’t engaged and have the knowledge to use it. Creating Smart Cities is only a part of transformative process that cities will endure; the other part is to figure out how these new cities will, as Littlefield said, remake themselves into better places to live for the people who live in them.

Smart Economy

This dimension covers the way cities encourage research and innovation development in companies and universities, and entrepreneurship in the city. Additionally, it comprises the growth of cities by the use of ICT-enabled innovation and the creation of new business models and products. Examples of this dimension are the development of e-commerce and e-business in a city, which in the last couple decades has had a rise in popularity, due to the fact that it greatly reduces infrastructure and logistics costs.

Smart Governance

The slow and complicated government processes, which characterize many countries, are always been considered as a major obstacle for the development of changes and innovative advances that can induce, on the long or short term, a boost in the economy of a country. To change this reality, many governments are beginning to implement ICT tools, like e-Government tools, which allow them to use the services offered to the citizens by the
government with a more simple and rapid approach, or the e-Democracy tools that allow the active participation of the citizens in the city’s administration proceedings. These new ways of offering government’s services and information to the citizens also could allow more transparent processes and thus, more confidence in the government’s way of doing things.

In this dimension, ICTs (Hardware, software and Infrastructure) are used to provide services and interactions with the public and even with other cities or nations via the Internet. The objective is to include transparency and open data, to encourage citizens to be an active part of the decision-making process and give them a sense of empowerment. This dimension is a transversal factor and in a way takes part in other smart city dimensions, like in the case of public lighting or traffic control, which are part of the Smart Environment and Smart Mobility dimensions, respectively.

**Smart Environment**

This dimension includes the use of ICT in the management of energy and natural resources in the city. Smart Lighting, Smart Grid, Smart Metering, pollution control and monitoring, renovation of buildings and amenities, green buildings, green urban planning and improving the management of both water and waste systems are some example of the technologies and initiatives this dimension covers. Furthermore, the gathering of data about energy consumption, and its use to create plans and policies to reduce pollution and achieve environmental sustainability objectives, is also part of this dimensions objectives.

As we all know, the protection of the environment is a priority for everyone today and this can be achieved by the improvement of the management of natural resources available and by a better control of the recollection and processing of waste, optimizing the recollection routes with sensors in the garbage containers, and focusing on reducing its creation and thus, incrementing the recycling percentages. Likewise, by monitoring the air pollution with sensors scattered throughout the city, it can be optimized the decision making process aimed at improving environmental conditions. Lastly, with an improvement in the water management system it can be achieved the reduction of waste, by increasing the network’s monitoring through sensors, or with the recycling of the waters that are not meant for consumption purpose.
Regarding the Smart Grid and the use of alternative renewable sources of energy, it can be said that many of the Smart City initiatives and projects in execution today are pointing to achieve the implementation of both. With the transformation of the traditional electric grid to a Smart Grid, the cities are trying to accomplish a more efficient and intelligent grid that can respond to the citizens’ necessities in a dynamic and proactive way, by integrating the actions and behaviors of the different users that are connected to it, with the purpose of achieving the electricity demand in a more sustainable, economic and safe way. On the other hand, by searching for alternative renewable sources of energy and integrating them in the grid, a better balance of the charges can be achieved, improving the environmental conditions by depending on clean energy sources and also, allowing better services for the citizens with a more reliable grid.

**Smart Living**

Smart Living is linked to high levels of social cohesion and social capital. This dimension is directly related to improving the quality of life of the citizens, by improving the services that the public administration offers to them and their sense of fulfillment and security in the city, for example, by investing in upgrading cultural facilities and public spaces. Also, thanks to the use of ICTs, cities can get useful information, which helps in providing a better lifestyle for its citizens. Regarding the security aspect of the citizens, at present, there are software that allow to analyze automatically the videos of the existing public and private CCTV networks, with the purpose of notifying in real-time to the person in charge whenever the video camera registered a critic event previously defined, allowing it to inform the situation to the corresponding authorities.

Furthermore, the Smart Living dimension focuses on promoting the active social participation of its citizens in the use of the new technologies and services available in the city. The purpose of this is diminishing the digital divide by looking to educate and include everyone in this new technological age. Also, thanks to the technological improvement, it can be offered a more efficient and effective education, creating better and innovative learning processes for the students and teachers. Some of the new and interactive ways of teaching consist of eBooks, Interactive Multimedia Boards and teleconference with other schools in real time. Finally, the enhancement and the maintenance of the cultural heritage and assets of the cities its comprised in this dimension, with the purpose of exploiting its potentials through ICTs, creating services in support of tourism, culture and leisure, like
digital tours in museums and through the cities monuments, enhanced reality, digital explorations and cultural maps, digital points of information using applications based on enhanced reality and Near Field Communication (NFC) technologies.

**Smart Mobility**

Problems related with increasing traffic congestion and the air and noise pollution that arises from this, entail to search for alternative options associated with the transportation of people and goods in urban settings, which can continue to offer the same or better level of services to the users and, at the same time, diminish the negative impact that congestions brings with it.

This dimension covers the issues mentioned above by working with the public and private transportation and logistics systems with the support of ICTs to provide a better service in which citizens and companies in the city can use many types of transportation (bicycles, buses, trains, trams, metro and private cars) to arrive to the places desired in a more sustainable way, by prioritizing the use of clean and often non-motorized options without affecting the comfort of the citizens. Moreover, the new systems gather information from meters, buses, bus stops, and other devices in the city through sensors and share it with citizens, through online platforms and applications, in order to save time and improve commuting efficiency, saving costs and reducing CO2 emissions. In addition to the implementation of this new services, government cities are encouraging eco-friendly and sustainable transportation by creating more cycling and pedestrian roads, and promoting changes in the way people move around the city, by supporting car-pooling and car sharing services and electric and hybrid cars as a substitution to traditional fuel cars.

These dimensions are a way to understand the issues the cities are tackling by adopting new methods to provide the traditional services in the cities. The improvements on each of the dimensions are the key to reaching the goal of being a Smart City. It is safe to mention that different cities focus their efforts in different dimensions at the early stages of the change, tackling the problems they deem more important, but their ideal goal must be the same, achieving sustainability in all aspects of the city, through the use of Internet of Things and ICTs.

Given the current problematics that cities are experiencing, like the ones mentioned above, it can be agreed that the traditional ways of dealing with them, like creating
additional physical infrastructure, expanding the electric grid or the water and sewer systems, won't work anymore, because of the limitations in the resources and spaces available. The Smart City is the answer to change the traditional ways of dealing with these problems, by using the technology to provide the services that all the citizens require from the city’s system (roads, basic utilities, schools, healthcare, etc). However, one of the challenges related to the creation of the Smart City initiatives and projects, is that they are expensive and a lot of the technology used in these kinds of projects is relatively new, increasing the uncertainties related to them, and at the same time increasing the risk associated to the investment in these projects. In fact, some of these technologic advances are so new and complex, that financers don’t have an established track record to compare and make decisions, which makes securing capital investment even more challenging (Smart Cities Council, 2013). Fortunately, thanks to the rising concerns regarding city related problematics and the success that many Smart City initiatives have had, today there are various financing tools available throughout the world to support cities and governments in the payment of Smart City projects.

1.3 The Financing Challenge

Cities produce around 80% of a country GDP, and are considered as critical economic hubs that contribute to national stability and growth, but they are generally constrained in resources limiting its economic development. Today, cities compete to install the digital foundations for what it may seem as its prosperity, because in the near future, the cities that can offer the best quality of life and business conditions will be the ones that will grow more quickly. The two major drivers of Smart City developments are that they increase the competitiveness of a city and its resilience (Smart Cities Council, 2013). Hence, public officials, scholars, businessmen and citizens recognize the important role ICT plays in enhancing the physical infrastructure of the cities, its economic competitiveness, environmental sustainability and its livability.

Over the course of the coming years, the expected trend is that governments, NGOs and enterprises around the world will spend time, resources and efforts in building or transforming cities into Smart Cities through Green Field and Brown Field projects, respectively. Some examples of the importance that the Smart City movement has today
can be seen in programs, initiatives, entities and organizations that have emerged in recent years, like the “100 Smart Cities project in India”, India Smart Cities, Amsterdam Smart City (ASC) innovation platform, Copenhagen Connecting, BCN Smart City, Japan Smart City Portal, Smart America a White House Presidential Innovation Fellow project, China’s 12th Five-Year Plan, EU-China SmartCities, UK-China SmartCities, IBM Smart City, IEEE Smart City Initiative, Cisco’s Smart+Connected Communities and Smart+Connected City, the Smart Cities Council, C40, Smart City Expo World Congress, to name a few.

In a worldwide Smart City movement, where a complex mix of players has emerged, each player sees the city through different perspectives that include a range of problems and methods to solve them. One of these players is the private sector, comprised by engineers and technology companies, which view the city as a complex system of systems, with multiple layers that can be improved through the use of ICTs and more importantly, the Internet of Things. On the other hand, architects and nongovernmental organizations (NGOs) see the city in terms of people, social inclusion, and a sense of space, having as a priority the improvement of the quality of life of the citizens. Finally, the government leaders are more concerned with the economic growth of the city and with improving or creating city services, by changing policies and supporting new paradigms. But, regardless of their different points of view, most of these players agree on a common vision, which consist in making the cities smarter and more sustainable (Falconer & Mitchell, 2012).

But building a Smart City requires the understanding that cities are complex interconnected systems, and that the use of technology, like the Internet of Things, is the key to unlock the potential of their interconnected nature. Nobody can deny that the world is getting smarter. And with the appearance of more connected electronic devices and everyday things, global companies have understood the importance of the Internet of Things (IoT) in this new vision of the world. Major players like Cisco, IBM, Qualcomm, Intel, Samsung, etc. have started investing massively to support the adoption of the IoT (Kolhe, 2014). The connections between things and people created by the use of the Internet of Things and supported by networked processes, enables the transformation of data into actionable information, used to do things that weren’t possible before or to do the existing ones better. With these new technologies it is possible to discover more quickly patterns and trends, and predict and prepare for anything from bus or assembly line breakdowns to natural disasters and quick surges in product demand (Chambers & Elfrink,
2014). The possibilities are endless when everything is connected; and the Internet of Things is the channel that connects the environment with the people who exist within it. It is how people influence the existing connections within the city systems and the data those connections produce to make it meaningful, in order to make better decisions in their everyday life activities; and is how policymakers improve their decision-making process, when modifying or eliminating regulations, laws and ordinances.

Certainly, in the world of technology innovation the next game-changing advance is the Internet of Things, and all the phases to make it happen are being developed. From a strong network infrastructure and millions of Smart Devices, to multiple ordinary things being made smart through the incorporation of sensors and the creation of Big Data and analytics frameworks needed to process all the data these sensors send; all of these united to create the vision of the future of the Smart City. However, there is a problem with achieving that goal. According to Cisco, it has been demonstrated that all of this is possible worldwide from a technology perspective, the problem lies, in the majority of the cities in the need of a policy framework that governs this new sector, the financing that enables a real impact for the citizens and a solid business model to install these technology innovations throughout cities and generate revenues.

“Wisely funding technology investments is critical to the realization of smarter cities. Certainly some technology investments are a one-time event, but most are operationalized in the context of projects. These projects are often complex undertakings, involving longtime horizons, multiple stakeholders and risk, which causes that would-be investors see them as high risk investments, requiring guarantees or other forms of credit support” (The Center for Urban Innovation at Arizona State University, 2013).

Normally, to accept or decline new projects, financiers assess similar capital projects to understand the expected feasibility and profitability of these. However, in order to do this assessment with capital intensive projects that are bound to new technologies can be a challenge, due to the limited information available on how the project might perform, causing that the risk associated with the investment increases and so does the capital’s cost. The fact that many Smart City technologies are relatively new and that there aren’t many studies available that compare the various financing tools to fund Smart City and IoT investments, made that some of the first projects in these areas ended in costly mistakes, because the projects were realized only with the knowledge and resources available, that
weren’t appropriate to back up all the decisions that had to be made (The Center for Urban Innovation at Arizona State University, 2013).

When evaluating which type of financing to select for any kind of project, decision makers must have in mind that different kinds of projects in each city can demand different types of financing, that’s why in the evaluation process having the right amount of information is essential to make the “correct” decision. Financing is a complex method to pay for any kind of investment, particularly for new technology projects, as are the Smart City and IoT projects, which have many variables to take into account; variables like the expected duration of the financing, the number of interested parties on the decision making process of the financing for the project, conflicting interests, like in projects related with city infrastructure or with a Public Private Partnership (PPP), the risk associated with the investment, for the investors and for the borrowers and incentives related to the project that can lower its risks. Financing tools are just instruments that simplify the process of borrowing capital now and repay it later, over a period of time agreed upon by the parts, plus the respective interests incurred, and for cities interested in upgrading their infrastructures and services, there are nothing more than a mean to achieve this end. On the other hand for an investor, the end in financing a project is to gain a significant return with an acceptable level of risk. Accordingly, it’s clear that different parties involved in financing Smart City projects or projects of any kind have in mind very different goals to achieve with these investments.

Financing can originate from two channels, direct investment and indirect or intermediated investment (Ferrer, 2013). In the first channel, direct investment, the capital received comes directly from the capital owner, and it is given to the project owners in exchange for a promise of return in terms previously agreed. Financing methods which use this channel come mostly from the private sector and investors usually require a guarantee of return in case the project does not meet its objective. One financing method which has been gaining strength in the last few years is crowdfunding. This method is an example of direct investment, but what makes it peculiar is that the capital for the financing comes from people around the world, which financially contribute to the development of the idea, but usually with small amounts of money, so the risk is minimum and the owner of the idea has less risk too, because in this type of financing, he/she usually does not have the pressure of paying interests and paying back the money in case the project is unsuccessful.
The second channel is indirect investment, in which the process of receiving the funding has an intermediary, who funds the project or initiative but the capital comes from other stakeholders. Government funding, of projects beneficial to its population, are usually in this category, a good example of indirect investment is when the government supports a project, by financing it with taxpayers’ money.

There are times in which the public and private sector share a goal in which both parties have a benefit. In such cases, the private sector usually provides a high percentage of the capital needed for the project development and the public sector provides permission for the use of public spaces and implements mechanisms to lower the financial risk of the private sector. The arrangements made by both parties are typically medium-long term and both parties share the risk of the project failing.

Finding methods to finance the IoT projects for the Smart City remains a significant challenge around the world, due to the fact that public financing is not enough to fund the needed investments. Cities with projects to upgrade their infrastructures with the implementations of Smart Technologies must find other kind of investors willing to finance them, whether they are from the private sector or through financial institutions. An important part of the challenge is to select the correct financial tool at the right time, because, even though there are numerous financing options available for various types of Smart City investments, not all are the most appropriate for any kind of projects. This problem is the bottleneck of the development of Smart Cities around the world.

1.4 State of the art

The main objective of this section is to collect information about the state-of-the-art of Financing and Funding Guidance for IoT projects for the Smart City in a systematic way. The aim is to provide a brief description of the tools, guides and publications, whose purpose is to help developers, entrepreneurs and city leaders find financing for their Internet of Things projects focused on Smart Cities, in order to understand the cities these publications are focused on, the types of projects included and the types of financing methods analyzed and thus, have a better view of the current knowledge in the matter and
recognize what is missing to build a better bridge between owners of projects and the people willing to invest in those projects to create IoT technology for Smart Cities.

From the research made, there were not papers or studies about financing specifically for IoT projects for the Smart City, but there were two reports about Financing and Funding Guidance for Smart City projects found: "The Smart Cities Financing Guide" created by the Smart Cities Council and “the Smart City: Development projects and Financing instruments” created by Cassa depositi e prestiti S.p.A. and the Politecnico di Torino. These two guides were analyzed with the purpose of understanding what has been done related to instruments with the scope of helping cities and regional governments to be better informed in the choices they have regarding financing for their Smart Cities projects. A description of the content these two guides provide is shown below:

**Smart Cities Financing Guide by the Smart Cities Council**

One entity or organization that has been active in the Smart City ambit is The Smart Cities Council, which is an alliance of successful technology companies in the areas of transportation, water, communications, energy and information management such as IBM, Cisco, Microsoft and GE. Their mission is to encourage the move towards smart and sustainable cities, by acting as an advisor and providing advocacy and action to help its partners achieve success in creating smarter and more sustainable cities. The Council has created 5 documents, all which are meant to help city leaders and planners in their way to turn their cities into Smart Cities. These documents are: the Smart Cities Open Data Guide, which is a compilation and analysis of best practices and mistakes made by cities around the world that already began their journey to become a data-driven city; The Smart Cities Readiness Guide, which is the first of its kind and it is meant to lead cities into the first steps towards becoming smart cities, measuring their progress and analyzing if the city is ready for the innovation towards its goal and suggesting paths to achieve it; The Smart Cities Apps Gallery, which contains over 100 free apps that cities have launched to be connected with their citizens and to be able to send and receive information from them 24/7. Some of these applications have been developed by the city itself and some by third-party developers; The Smart Cities: Best of the Best eBook, which contains a ranking of cities, such as the most innovative or inventive, who have begun the journey towards becoming Smart Cities, some who already have. The document also contains analysis of
cities that have made costly mistakes. Finally, there are predictions about the cities’ future development; and the Smart Cities Financing Guide, which provides analysis of 28 finance tools used in cities or municipalities aimed to help city leaders find financing for smart city projects.

Among these 5 documents created by the Smart Cities Council, the Smart Cities Financing Guide is the one that provides information about Financing Guidance for Smart City projects, which is the focus of this thesis and thus, a deeper analysis of this guide was made as follow.

This guide was developed by the Center for Urban Innovation at Arizona State University. It contains an analysis of 28 financing tools used by cities to fund their Smart city projects. The analysis was conducted based on information mainly about cities, states and municipalities in USA, although some of the financing tools are also used in other countries around the world. The methodology used by the experts was to give a description of each financing tool and for each one, give an example of a project that used this type of financing tool. Finally, the tool would be described as a set of characteristics to summarize the information and help decision makers in their job to find the best way to raise funds for the projects. The list of characteristics is the following:

- **Sources of Capital:** Where the money for the project comes from (Government, taxpayers, NGOs, etc.)
- **Number of parties:** Number and description of the parties involved in the negotiation.
- **Ease of securing financing:** The level of accessibility to this type of financing. The financing tools are given a qualification from 1 to 5 to be able to do comparisons between them.
- **Duration of financing:** The period of time in which the financing will be provided.
- **Risk to investors:** The financial risk of financing the project, which depends a lot on the parties involved, the technology to be used and the expected return on investment (if applicable). The financing tools are given a qualification from 1 to 5 to be able to do comparisons between them.
- **Risk to borrowers:** The risk derived from the commitments to paying back the capital borrowed from the investors and the probability of being able to pay the
capital in the future if the project is not successful. The financing tools are given a qualification from 1 to 5 to be able to do comparisons between them.

- **Tax implications:** This relates to the possibility of the government of giving exemption or reduction of the tax applied to the interests from the investment earned by investors, which is a method government uses to attract more investment into projects to make the city more sustainable.

- **Source of repayment:** The sources from which the capital invested and interests will be returned to the investors. In the majority of cases the source is the earnings from applying the new technology in the city.

- **Advantages:** Reasons why this financing tool could be a good choice to fund a Smart city project.

- **Disadvantages:** Difficulties in choosing this financial tool to fund a Smart City project.

Besides describing each one of the 28 financing tools, the guide also categorizes them in 4 groups, depending on the entities that provide the capital for the project. These 28 financing tools are divided into the 4 mentioned groups and a brief description of each group will be provided below.

- **Government-based Financing for Cities:** These are mainly debt instruments used by the government to attract investors. The government agrees to pay back the debt at a previously agreed interest and usually it is paid during the life of the project. This type of financing is very attractive to investors, because most of the tools in this group are tax exempt of the interests earned and thus, it is the most common to finance unproven technology projects. The financing tools that belong to this group are: General Obligation bonds, Revenue bonds, Industrial Revenue bonds, Green bonds, Qualified Energy Conservation bonds, Social Impact bonds, Public Benefits funds, Linked deposit programs, Energy efficiency loans, Property-Assessed Clean Energy, Greenhouse emissions allowance auctions and User fees.

- **Development Exactions:** These exactions are mainly fees that are charged to new developers in the city for the impact their development would cause to the city. These fees also serve as capital for sustainable growth of the city, but many states in USA are being sued because developers believe they are paying too much with
respect to the impact they may be causing. The financing tools that belong to this group are: Developer dedication requirements, Tap fees, Linkage fees and Impact fees.

- **Public and Private sectors together:** This group of financing tools enjoys the advantages from both sectors, the higher capital and human resources from the private sector and the accessibility to public places from the public sector, but it also needs more coordination from both sectors and the interest of both in the same project. The financing tools that belong to this group are: Public-private partnerships (PPP), Pay for performance, Securitization and structured finance and Catastrophe bonds.

- **Private Sector:** This type of financing tools gets funding for the projects from private investors and companies. These tools take advantage of the large pool of capital from them and it is very likely that the development of the technology of the project can be a great competitive advantage for these companies, but the risk of both the investors and borrowers tend to be higher, which is an important difficulty these type of financing tool has. The financing tools that belong to this group are: Loan Loss Reserve Fund (LRF), Debt service reserves, Loan guarantees, On-bill financing, Pool bond financing, Pooled lease-purchasing, Value Capture, Tax increment financing, Philanthropic opportunities, International non-governmental organizations (NGOs) and Combining financing options.

This guide is free, and is available to decision makers looking to select the right financing option for their projects. It has to be noted that not every tool mentioned in the guide is available in every jurisdiction around the world, but the financing tools collection exposed is a good starting point for exploring some of the options available. According to the study made, the authors consider that the city leaders may need to consider some of the non-traditional financing arrangements that may prove a better fit for the kinds of smart technologies they want to see in their communities.

“Like hammers and screw drivers, these tools are good for different kinds of investment activities. Some require several partners and more coordination. Others rely on the coercive powers of government. Still others try to tap the deeper reservoirs of private capital to help build the smarter infrastructures needed for tomorrow’s cities” (The Center for Urban Innovation at Arizona State University, 2013).
In the paragraph above, the author advises to realize a deep and thoughtful investigation before taking any decision or action relate to the financing of Smart City’s projects or any kind of project in order to diminish the risks and make a better management of the resources and options available.

**Smart City: development projects and financing instruments by Cassa depositi e prestiti S.p.A. and the Politecnico di Torino.**

This report was released in 2013 and intends to find a relation between the types of Smart City projects in general and the financing tools best suited to fund these projects. The investigation focuses its analysis in the financing tools available on the European markets, with special attention on the Italian market, such as the financing provided by the program Horizon 2020 from the European Union and analyzes some public-private partnerships and project financing that have been used by European Smart City projects. In order to do this, the authors, based on several Smart City definitions made by other experts, created a definition of their own, which states that: "a city can be considered smart if, according to a strategic vision, uses its ICT tools as an innovative support to the management and the delivery of public services, also thanks to the help of Public-Private Partnership, to improve the livability of its citizens. It also uses real-time information gathered from various areas, and the city's resources, both tangible and intangible. Finally, it adapts itself to the needs of the users and thus, achieve sustainable development". The authors also divided the Smart City projects analyzed into areas of applications, and for each one of these, the experts evaluated their economic sustainability. In order to do that, they describe each one of them, the main applications and services that are in the market, the characteristics of said market and the most used business models in it. The areas of applications and its sub-areas used in this report are shown in Table 3.

In this report it is said that the path at the base of the creation of Smart Cities needs nonstop innovations and investments, which the Public Administration cannot cope alone; but in some cases the implementation of public funds is a must, for example in cases where the technology is not mature enough and thus, the risk of investment is too high. It is for this reason that to support the development of Smart City projects there is a need to include private capital in its realizations, through Public-Private partnerships or as stand-alone investments from the private sector, stimulated by the Public Administration through
a business-friendly environment with positive economic, environmental and social implications for the entire urban frame.

<table>
<thead>
<tr>
<th>Areas of application</th>
<th>Sub-area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility and Transport</td>
<td>City Logistics</td>
</tr>
<tr>
<td></td>
<td>Mobility Services</td>
</tr>
<tr>
<td></td>
<td>Infomobility</td>
</tr>
<tr>
<td>Buildings</td>
<td>Building Management Systems</td>
</tr>
<tr>
<td></td>
<td>Home Energy Management</td>
</tr>
<tr>
<td></td>
<td>Smart Appliances</td>
</tr>
<tr>
<td>Government</td>
<td>E-government and E-democracy</td>
</tr>
<tr>
<td></td>
<td>Transparency</td>
</tr>
<tr>
<td></td>
<td>Procurement</td>
</tr>
<tr>
<td>Economy and People</td>
<td>Business &amp; Entrepreneurship</td>
</tr>
<tr>
<td></td>
<td>ICT Diffusion</td>
</tr>
<tr>
<td></td>
<td>Human Capital</td>
</tr>
<tr>
<td>Energy</td>
<td>Smart Grid</td>
</tr>
<tr>
<td></td>
<td>Renewable Energies</td>
</tr>
<tr>
<td></td>
<td>Public Lighting</td>
</tr>
<tr>
<td>Living</td>
<td>Education</td>
</tr>
<tr>
<td></td>
<td>Healthcare</td>
</tr>
<tr>
<td></td>
<td>Leisure &amp; Hospitality</td>
</tr>
<tr>
<td></td>
<td>Public Assets Management</td>
</tr>
<tr>
<td></td>
<td>Public Safety</td>
</tr>
<tr>
<td></td>
<td>Welfare Services</td>
</tr>
</tbody>
</table>

Table 3. Areas of application of the Smart City by Cassa depositi e prestiti.

Among the financial tools that exist today, the report presented a series of instruments classified in 3 main sections, EU Instruments, Private-Public Partnerships and Project Financing, according to the nature of the financing tools, and finally a recollection of other instruments of private finance that did not correspond to any of the 3 sections above mentioned. Below a brief description of the content of the sections is presented:

- EU Instruments: In this section there are considered funds for the urban developments and those related to the support of the SMEs or the development of urban capital. These funds were sub-divided, according to their characteristics, into three groups:
  - Programs directly managed by the EU:
- Horizon 2020.
- COSME.
- LIFE +.

- Structural Funds, which are funds indirectly managed by the EU, which included, among others:
  - European Regional Development Fund (ERDF).
  - European Social Fund (ESF).

- EIB Instruments (European Investment Bank Instruments) used to finance Smart City Initiatives are:
  - ELENA (European Local Energy Assistance).
  - JESSICA (Joint European Support for Sustainable Investment in City Areas).
  - JEREMIE (Joint European Resources for Micro to Medium Enterprises).
  - Europe 2020 Project Bond Initiative (PBI).
  - Risk Sharing Finance Facility (RSFF).

- Private-Public Partnerships (PPP): intended in the report as contracts based on cooperation between the public and private sectors, where their respective abilities are combined to develop public works or works useful for the citizens for the management of related services. To consider a contract as a PPP contract, the authors state that it must have, mainly, this 5 characteristics:
  - A long-term contract between the Public Administration and one or more private enterprises.
  - Some risks must be transferred to the private sector.
  - Specification of the output's performance of the project, over those of the inputs.
  - Use of private funding (often in the form of project financing).
  - And, the realization of payments to the private partner(s) by the users of the services, the Public Administration or both.

The financing instruments analyzed in this report, belonging to the Public-Private Partnerships and in line with the Smart City projects are shown below:

- ESCO (Energy Service Company).
- The Urban Transformation Company (STU, by its acronym in Italian).
- Finance lease (leasing in building).
- Sponsorship contracts.
- Social Impact Bond (SIB).

**Project Financing (PF):** defined as a structured financing that, compared with traditional corporate finance, evaluates the economic-financial balance of a specific project, and it does not evaluate the economic-financial balance of the enterprise as a whole, considering the project independently from other initiatives of the enterprise.

The authors state that the Project Financing can be considered as a suitable financial instrument for the Smart City projects, having in mind that the PF has had a wide application in the construction of tangible infrastructures projects, because they are characterized by physical assets that can be used as collaterals, a low risk profile, more consolidated practices and identifiable cash flows. Although, in fact, the Smart City initiatives are characterized by a greater intangibility and innovation, there are areas where the technological maturity allows greater certainty about future cash flows, giving a lower risk for the investments, making the Project Financing instrument suitable for some Smart City projects. In addition, the PFs have the advantage of having a single center of responsibility during the various stages of design and construction of the project and that the existence of a physical asset can allow to have a warranty of the investment.

Furthermore, according to the authors, the Project Financing is an advantageous mechanism for the Public Administration, due to the fact that the private sector has the responsibility of designing the services, releasing the Public Administration of this obligation, for which in many cases would not have the adequate technical skills to be in charge of this. Also, PF gives to the Public Administration the possibility of creating public structures without increasing the public debts, to transfer the risks of design, construction and management to the private partner and to tie the coverage of the investment to rates paid by the users or to an annual fee related to savings of the operation and maintenance of the works made by the investment.

Finally, it is emphasized that the PF is a very demanding financing instrument, characterized by high transaction costs aimed at regulating the contractual relations and reduce the risk associated to the information asymmetry.

**Other instruments of private finance explored in the report were:**
- The MiniBonds.
Lastly, the authors created a matrix to confront the financing tools mentioned before to the areas of application of the Smart Cities and its sub-areas; and based on the data gathered (technology, business models, etc) evaluate the adaptability of these areas of application with the financing tools. The matrix has the purpose of helping the principal stakeholders to follow the continuous path of innovation that the Smart City represents. The authors defined the degree of adaptability of the instrument to the field of application considering the technology, the context of reference and the business models. They also express the degree of adaptability of the instrument to the field of application providing an indication on an ordinal scale, in the form of pie charts in the matrix, according with the following logic:

- Very suitable instrument to fund initiatives within the field of application.
- Average suitable instrument to fund initiatives within the field of application.
- Poorly suitable instrument to fund initiatives within the field of application.

In the concluding remarks of the report, the authors mention the importance of financing in the planning stage of the road towards a Smart City, due to the fact that in order to achieve that goal, a medium-long term plan for the changes and upgrades of a city is needed and financing is crucial to make the “right” decisions about the future of the city. They also state that the financing of a Smart City project can and should be a mix of different financing tools. This mix can take advantage of the strengths and weaknesses of different financing tools, which for example, are commonly, used in different stages of the lifetime of the projects because of the higher risk of the project’s early stages. Moreover, the involvement of the private sector in the Smart City is mostly found in PPPs but still there are some barriers, like high transactional costs, that lower the attractiveness of investing in these types of projects. Finally, it is mentioned the importance of alliances between cities to share knowledge and even resources to reach the goal of becoming a Smart City with less risk and investing less time, and thus, making the investment in Smart City projects more attractive, due to the fact that the economic stability of 2 or more cities is usually less volatile than just one city.
Chapter 2

Objectives and Methodology

This study aims to identify the financing instruments available which are used by Internet of Things (IoT) projects for the Smart City and also provide a clear and coherent method to display the information about the relationship between the financing instruments used by Internet of Things projects implemented in the different fields of application of the Smart City. However, in order to achieve this, it is imperative to find the cities in the forefront in terms of Smart City development, the Internet of Things projects implemented in them and the financing methods used by them.

General Objective

Investigate the financial instruments that can be used by Internet of Things projects for the Smart City and to find if currently, there is a correlation between these financing instruments used for these projects and the dimensions of the Smart City.

As mentioned in the previous chapter, the Smart Cities are currently one of the best solutions to the problems of overpopulation, scarcity of natural resources and environmental pollution, which are threatening the wellbeing of the people in cities worldwide. There are two main drivers in the evolution of Smart City, one being the development of the technology capable of making the everyday processes in a city sustainable by providing ways of performing them using less resources and if possible with the use of renewable resources. The other driver of the Smart City is financing the projects and initiatives from governments and stakeholders, because even though, the technology for the Smart City is advancing, thanks to the development of Internet of Things and Smart Devices targeted at the Smart City, it is still slowed by the lack of investment capital in these types of projects. Many ideas based on IoT technology that could improve the sustainability of a city’s processes are been turned down by lack of resources to make the projects a reality. The irony is that there is capital to make this possible, but sometimes project owners and cities do not know where to look for it. That’s the reason this study is
being done; to provide information about the financing tools these entrepreneurs can use according to the dimension of the Smart City or the specific field their IoT projects are targeting.

**Specific Objectives**

- Understand what a Smart city is, its dimensions, its importance today and the role of Internet of Things technologies in its development, through a thorough investigation on the subject, in academics database, reports, news and other source of reliable information.
- Understand what is the Internet of Things, its evolution throughout time, its technologies and how it relates with the Smart City projects, through a thorough investigation on the subject, in academics database, reports, news and other source of reliable information.
- Identify the forerunners cities in Smart City development and technologic advance, based on some of the international rankings for Smart Cities supported by governments, technology companies and academics.
- Identify, from the Smart City projects belonging to each of the selected cities, the Internet of Things projects for the Smart City, aggregating them in reference to the dimensions of the Smart Cities.
- Identify the financing instruments used in the Internet of Things projects for the Smart City, classifying them in one of the 3 financing categories (Public financing, Private financing and Public-Private-Partnership).
- Compare the different financing categories available and the Smart City dimensions, with the purpose of creating a guide to choose the best financing match for future Internet of Things projects for the Smart City.
- Present cases regarding the different Internet of Things projects for the Smart City and the financing tools used in these projects as legitimate testimonies of their existence, describing the projects’ objectives, the technology used and the way they were financed.
Methodology

As mentioned in Chapter 1, there is little information on the web about financing guidance for Smart City projects and about the projects themselves, due to the fact that only in recent years, the interest in developing initiatives for Smart Cities has increased and thus, the willingness of the public and private sector to finance these types of projects. This becomes a complication in terms of gathering data about financing tools and Smart City projects worldwide and because of this, it was decided that the sample of cities, and hence the Internet of Things projects for the Smart City, to take into consideration for the following analysis would be selected from information gathered in academic search engines and databases, in news related to the subject from reliable sources, reports, papers, rankings and events concerning the Smart Cities.

After doing an extensive research in academic databases such as IEEE, CRC Press, ASTM and Ebsco, and visiting many official websites of companies, international organizations and governments, related to our subjects of interest (Internet of things, IoT technologies, Internet of Things projects for the Smart City, and financing tools for this kind of projects), with the purpose of obtaining a better perspective on the development of the Smart City concept and the project’s initiatives available in the world, it was concluded that the sample of cities to analyze would be selected through a comparative analysis of different international Smart City rankings available and the number of active Internet of Things projects for the Smart City in these cities.

The selection criteria for the cities presented in the following analysis was made according to the rankings below:

- Boyd Cohen Top lists of Smart Cities
- C40 Cities
- IBM Smart City Challenge
- Smart City Council: “The Best of the Best”
- Smart City Expo World Congress Awards
- Japan Smart City Portal
- Intelligent Community Forum: Smart21 and Top 7
- IEEE Smart Cities Initiative
These rankings are supported by governments, leading companies in technology, and academics and experts in technology, energy and green initiatives, the selection criteria to rank the cities were made according to the development each one has in terms of technological developments, Smart City initiatives, involvement of the citizens in the use of the new technologies and government guidance.

Once the cities to be considered in the study were selected, we proceeded to the selection of the projects. The selection of the projects and initiatives began with a filter, in which Smart City projects that did not use Internet of Things technology were excluded, since the focus of the study is on Internet of Things projects for the Smart City. After the selection of the projects, they were subdivided by Smart City dimension, the specific issue addressed within the Smart City dimension and type of financing used, in order to have a clear view of the relationship between Smart City dimension and the types of financing used by cities and project owners.

Finally, having gathered the pertinent information, in the following chapter the analysis of this study will be done. The analysis will mainly consist of an overview, for each Smart City dimension and specific field relevant to the study, a description of the type of projects and initiatives developed in the cities previously selected and with the aid of graphics, an analysis of the financing tools used to fund them, with the purpose of finding if there is a connection between the Smart City dimensions and the financing method used. In addition, 3 case studies for Barcelona, Boston and Rio de Janeiro, which excel in terms of innovation or technologic advance in their regions has been made.
Chapter 3

Analysis

The purpose of this analysis is to find the connection between the sector of a Smart City that a project aims to improve and the type of financing used to make the project possible. It is important to remind that only projects that use IoT technology were taken into account, since this specific group is the focus of the thesis.

Overview

At first, the best cities in terms of Smart city according to experts in the subject and technology companies were selected as the starting point for the research of IoT projects. The result of this step was a selection of 25 cities (See List Below) and for each one a thorough search for Smart City projects was made with a focus on projects whose core was based on Internet of Things. Through the analysis specific attention was made to the financing used to develop each project and the actors involved, aggregating them in Public financing, Private financing, and Public-Private Partnership financing.

Sample of Cities Selected

Europe

- Amsterdam (Netherlands)
- Barcelona (Spain)
- Berlin (Germany)
- Copenhagen (Denmark)
- Dublin (Ireland)
- Frankfurt (Germany)
- Helsinki (Finland)
- Heraklion (Greece)
- London (UK)
- Nice (France)
- Oslo (Norway)
- Oulu (Finland)
- Paris (France)
- Santander (Spain)

North America

- Arlington County (USA)
- Boston (USA)
- Chicago (USA)
- Columbus (USA)
- Kansas City (USA)
- New York (USA)
- Toronto (Canada)
South America

- Rio de Janeiro (Brazil)
- Santiago (Chile)

Asia

- Seoul (South Korea)
- Da Nang (Vietnam)

From this sample of cities, 112 projects were selected and analyzed for the study, all of them implementing IoT technologies to improve a certain aspect of a Smart City.

**Financing Tools**

In the last 5 decades, the phenomenon of globalization has led people around the globe to be more connected than ever before. This has produced many changes in the world, within the most important are: the free sharing of information between people from most countries, the economic growth of many countries thanks to alliances and to the increasing ability to invest and find investment around the globe. The free sharing of information has boosted the development and growth of knowledge in many fields, but most likely the development of new technology has been the most impacted by this trend. Just as important is the fact that everyday there are more ways to find financing for projects, initiatives or generally anything, but that does not mean that it is easier. All the financing tools have risks for all parties and the correct management of these risks is critical in making a project a success or a failure.

The current desire to achieve sustainability in cities and ideally everywhere has developed the interest in investing in technology and projects that aim to achieve sustainability in any given field, and thus the interest in investing in projects aimed at Smart Cities. The financing tools described in this study are not explicitly for Smart City projects; instead they are the tools a city has for finding funding for their projects. Some of these tools are not specifically for Cities but also for entrepreneurs interested in the Smart City. For a better understanding of the financing tools, they will be classified in 3 main groups, depending on the parties providing the financing.

The groups are Public Financing, Private Financing and Public-Private Partnerships.
Public Financing

The financing tools in this group are characterized by the fact that the financing is provided by the government, usually from the city, but it could be from the country or, in the case of Europe, by the European Union. In general, this type of financing is among the safest for the investor, because the probability that a whole city is unable to repay the debt is lower than a single individual or organization. It is important to notice that these financial tools are not linked directly to Smart City projects, but are the ones governments use to finance projects in their jurisdiction and for the benefit of their community. The growing importance of becoming Smart Cities is making the government invest more of the capital gathered by these tools into Smart City projects and into IoT technology that can be beneficial to the city's development. Nonetheless, there are financing tools that are tightly linked to Smart City projects, i.e. Green Bonds to projects in the Smart Environment Dimension. The financial tools in this group will be described below.

Government Bonds

A government bond is a debt tool used by governments to support spending in their domain. The national, city or municipal government can sell the bonds, but the bonds must be used to finance a project in its respective jurisdiction. The bonds are sold to investors and they are backed by the full faith of said jurisdiction. It is the investor's job to evaluate the risk of the city or country, the political risk and the risk of the inflation of the currency of the bond, since the majority of these bonds are sold in the local currency of the country of issue. The source of the capital for the payment of the debt and the type of project to be financed differentiate the type of bond issued. The main types of government bonds that are being used for funding Smart City Projects are:

- **General Obligation Bonds**: These bonds are used by any project beneficial to the jurisdiction of the government who sold it and the payment is backed by the taxpayers’ money.

- **Revenue Bonds**: The debt linked to these bonds is backed by the revenue of the project or initiative that is being financed by the bonds. In this case, the risk of the investor is usually higher, since it is possible that the success of said project does not meet the expectations.

- **Green Bonds**: These bonds are used to finance project that aim at reducing the
carbon footprint of a city or nation or generating clean power from non-fuel energy. This type of bond is very common in Smart City projects tackling the Smart Environment and Smart Mobility dimensions. The issue with green bonds is that the risk to the investors is high, because of the uncertainty of the success of new technology on these fields, but the revenue gained from them are usually tax free.

- **Qualified Energy Conservation Bonds:** As the name suggests, these bonds are used to finance projects that aim to reduce the consumption of energy in a location and/or use renewable energy sources to achieve that.

**Energy Efficient Loans**
This type of loan is relatively new, but has a huge potential in terms of reduction in energy consumption in a population, as it has already happened in Asia and USA. The purpose of Energy Efficient Loans is to support the population of a city to improve the energy consumption in their homes, i.e. by installing solar panels. The government makes the loan and uses its capital to finance the improvements on the citizen’s household and by doing this, the citizen can have access to a very low interest rate in the loan, since the risk of the investor decreases by loaning the capital to the government instead of loaning it to a bank.

**Greenhouse Emissions Allowance Auctions**
This financing tool was created thanks to the increasing awareness in the last few decades about Greenhouse Emissions and their impact in the environment and our lives and it is most used in North America. The government makes a pool of the total GE emissions allowed by law and auctions them to the companies creating these emissions. This method raises capital that can be used to develop programs to reduce the impact of GE emissions, while at the same time not surpassing the GE emissions allowed by the jurisdiction of the government auctioning them.

**User Fees**
User fees are small payments that citizens make for using public services, like paying a toll when entering the city or paying a little extra for a parking ticket to be able to do the payment online. The government can use this money to finance projects linked to these fees to improve the city’s infrastructure.
EU Supported Programs

- **FP7**: The EU’s Seventh Framework Programme for Research and Technological Development, also known as FP7, successor of the FP6, was the European Union’s Research and Innovation funding program during 7 years. The program started in 2007 and ended in 2013, and had a total budget of over € 50 billion, which reflects the high priority that Europe is giving to research. The FP7 responded to Europe’s needs of jobs creations and competitiveness, helping Europe to maintain its leadership in the global knowledge economy. The expenditure budget managed by the FP7 increased year by year, initiating in € 5,48 billion euro in 2007 and finalizing in € 10,84 billion by 2013. The FP7 was open to participation from any country in the world and the recipients of the funding are universities, research organizations, public or governmental administration, small or medium-sized enterprises and the technology industry, among others, in order to co-finance research, technological development and demonstration projects. The themes that the program sought to address were health, biotechnology, security, energy, transport, environment, ICTs, Euratom, ideas-ERC, food, agriculture and fisheries, among others. From the themes addressed by the FP7, the themes of ICTs, health, ideas-ERC and Euratom had the biggest amount of investments assigned in the whole duration of the program. The current program is Horizon 2020 but there are many projects funded under FP7 which are still active.

- **Horizon 2020**: The Horizon 2020 is the follow up programme to the FP7 and as it predecessor, it searches to drive economic growth and create new jobs, by investing in research, creating a future that is smart and sustainable. The Horizon 2020 program is backed up by Europe’s leaders and the Members of the European Parliament and it promises more breakthroughs and discoveries by taking great ideas from the lab to the market. The program will be active for a period of 7 years, from 2014 to 2020, and will have a budget of € 80 billion for funding available, in addition to the private investment that the program hopes to attract. Horizon 2020 is available for everyone, with a simpler and less time consuming structure, which removes barriers to innovation and facilities for the public and private sectors to work together.
- **Europe 2020**: Europe 2020 started in 2010 as the European Union’s ten-year jobs and growth strategy, to create the conditions for smart, sustainable and inclusive economy. It has 5 ambitious targets, to be achieved by the end of 2020, on employment, innovation, education, social inclusion and climate/energy, which each Member State works to reach in its own way. The progress towards the achievement of these targets is encouraged and monitored throughout the European Semester, which consists in the EU’s yearly cycle of economic and budgetary coordination.

- **COSME**: The Competitiveness of Enterprises and Small and Medium-sized Enterprises (SMEs), COSME, is an EU programme active from 2014 to 2020 with a budget of €2.3 billion. The areas that the program supports are classified in 4 categories:
  - Better access to finance for SMEs.
  - Access to markets.
  - Supporting entrepreneurs.
  - More favorable conditions for business creation and growth.

- **LIFE**: The LIFE program began in 1992 to contribute with the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value and, to the date, more than 3954 projects have been co-financed across the EU. There have been 4 phases of the LIFE program, named LIFE I (1992-1995), LIFE II (1996-1999), LIFE III (2000-2006), LIFE+ (2007-2013) and lastly LIFE regulation (2014-2020) that have contributed approximately with 3.1 billion euro to the protection of the environment. This program is managed by the European Commission, who has delegated some components of the program to the Executive Agency for Small and Medium-sized Enterprises (EASME).

- **JESSICA**: The Joint European Support for Sustainable Investment in City Areas or JESSICA initiative supports sustainable urban developments and regenerations through financial engineering mechanisms. The initiative belongs to the European Commission and it was developed in cooperation with the European Investment Bank or EIB and the Council of European Development Bank or CEB, and its aim
is to support projects to improve urban infrastructures, cultural sites, university buildings, redevelopment of brownfield sites, energy efficiency improvements, creation of new commercial floor space for SMEs, IT and Research and Development sector. The JESSICA initiative works by allocating contributions from the European Regional Development Fund or ERDF to Urban Development Funds or UDFs which then invest them in Public-Private Partnerships or other projects related with sustainable urban development, in the forms of equity, loans and/or guarantees.

- **ELENA**: The European Local Energy Assistance or ELENA is a program managed by the European Investment Bank, as a part of the EIB’s efforts to support the EU’s climate and energy policy objective. The ELENA program is funded through the European Commission’s Intelligent Energy Europe programme and it covers approximately 90% of the technical support cost needed to prepare, implement and finance the investment programs, by assisting with feasibility and market studies, program structuring, energy audits and tendering procedure preparation. By doing so, ELENA helps local and regional authorities to prepare solid business and technical plans for their energy efficiency or renewable energy projects, attracting private banks and other sources of funding. ELENA has as a goal to encourage and assist authorities in thinking ambitiously and in developing energy efficiency and renewable energy projects that could be escalated across the EU and for this purpose the joint EIB-European Commission initiative is planning to mobilize more than 1.6 billion euro in investments over the next few years. The projects eligible by the program ELENA can be related to improving the energy efficiency in buildings or street lighting, the integration of renewable energy sources in buildings, the renovation or installation of district heating systems or the implementation of energy efficient buses or transport that uses renewable energy.

- **JEREMIE**: The Joint European Resources for Micro to medium Enterprises or JEREMIE initiative endorses the use of financial engineering instruments to improve access to finance for SMEs through Structural Fund interventions. The JEREMIE initiative was developed by the European Commission with the support of the European Investment Fund, and it supports the creation of new business or the expansion of existing ones, the access to investment capital by enterprises
(SMEs) to modernize and diversify their activities, develop new products, secure and expand market access; the JEREMIE’s funds also support technological modernization of productive structures to help reach Low Carbon economy targets, productive investments which create and safeguard sustainable jobs and business oriented research, technology transfers, innovations and entrepreneurship. The JEREMIE initiative works by allocating to loans, guarantees or venture capital funds the contributions from the ERDF to invest them in enterprises. The returns from the investments are reinvested in enterprises, allowing the creation of a pool of funds that can be used many times, recycling public funds, leveraging capital and increasing the sustainability and the impact of public resources allocated to SMEs.

**Private Financing**

The importance of Smart Cities and the role of IoT technology in their development are at their highest point in time. Many cities around the world, like Copenhagen and Barcelona, are setting goals to become “completely smart” in a timeframe of 10 to 15 years and this trend is getting noticed by the private sector. Although the involvement of the private sector in projects for the Smart City are nowadays mostly through Public-Private Partnerships, some companies have analyzed some of the issues to be tackled by the Smart City and have found opportunities to build a profitable business. There are still few cases like these in the world compared to number of projects financed by PPPs and by the public sector, because the uncertainty of the new technology brings higher risk to the return of the investment (ROI) and since the main goal of private companies is usually high ROI, they tend not to take the risk by themselves and try to make a partnership with the government of the city to minimize the risk of the project or they just invest in more profitable and less riskier projects.

Private organizations have many financing tools available to finance projects on their own, as is well known in the business world. These tools are the basic tools most commercial organizations use to finance projects, improvements, expansions and releases of new products and services.
Loans
At a basic level, a loan is a debt that an individual, company or organization (Lender) acquires by reaching an agreement with another party (Borrower) to lend an asset (usually capital) from this party and to return it in the future with an interest rate added to the value of said asset. The amount and frequency of the payment(s) are agreed upon making the contract.

Investing from Revenues and/or Patrimony
Private organizations can use capital from the revenues from the past year or part of the patrimony of their shareholders to finance projects of interest to the organization. In regards to Smart City projects with IoT technology, due to the uncertainty of these types of projects have, shareholders are probably reluctant to invest in them, because they are taking all the risk of the project and the ROI of these types of projects nowadays is still low.

Public-Private Partnership (PPP) Financing
Most Smart City projects and IoT technology development require substantial amounts of capital during the lifetime of the project. This need of capital is one of the main reasons cities and Smart City project owners are trying to involve the private sector in their initiatives. The grade in which the private sector is involved in the project and, most importantly, finances it depends greatly on the uncertainty of the technology to be developed, the opportunity the investment in the sector provides and the advantages the city or project funders offer.

PPPs are agreements between a private partner and a government agency in which both parties join together to finance, build and operate a project or initiative for the benefit of the population in the jurisdiction of the government agency. The level of participation in financing, management and operation in the project of both parties is agreed before making the contract and is the main characteristic that differentiates the types of PPP agreements. It has been decided to group these in 3 main groups due to their similarities in terms of financing responsibilities of both parties, average duration of contracts, among others, as categorized by the World Bank.
Management and Operation & Maintenance (M and O&M) Contracts
These types of PPP are characterized by the fact that the private partner in the agreement has responsibilities that range from basic technical support to complete Operation and Maintenance depending on the contract signed. These contracts tend to be short-term agreements between 2 to 5 years. Another characteristic these contracts have in common is that both the private and public partners are responsible for the financing of the project, even though the government agency usually pays the private partner a fixed fee for providing the service agreed on the contract. The contract also contains whether or not the private partner is responsible for asset condition during the period of the contract and at the end of it.

Lease and Affermage Contracts
In this type of PPP the private partner provides the operation and maintenance of the project, just like Management and Operation & Maintenance Contracts, but it does not participate in the financing of the project. The duration of the contracts is medium, usually between 10 to 15 years. In addition, the private organization is not paid by the government agency but instead is paid by the consumers through an operator fee. In contracts like these, the private party does not have risk for initial investment, but in return has a higher operating risk.

The difference between leases and affermage contracts is which partner receives a fixed fee. In the lease, from the operator fee received by the private partner, a fixed fee is paid to the government agency as a lease fee, since they are the owners of the assets. On the other hand, in affermage contracts the private partner takes the affermage fee from the collected operator fees and gives the remainder to the government agency.

Concession and Build-Operate-Transfer (BOT) Contracts
Concessions and BOT contracts are contracts in which a private partner is awarded the rights to operate, manage and maintain a project beneficial to the city, but unlike the contracts mentioned before (M and O&M, and Lease and Affermage), in these contracts the private partner is in charge of most of the financing of the project, but the government agency usually keeps ownership of the assets.

Concessions are output based contracts in which the concessionaire (Private Partner) has
to meet certain performance standards during the delivery of the service. These contracts have a long-term duration, frequently between 25 to 30 years, after which the government agency gets its assets back. The concessionaire’s main sources of income are the consumers and from the revenue earned, it must pay the government agency a concession fee, which can be used for asset replacement during the duration of the concession.

In, Build-Operate-Transfer contracts, the government grants the private partner permission to create and operate a project, which at the end of the contract will become property of the government agency and operated by it too. The duration of the contract is variable, depending on the dimensions of the project. The private partner may choose how to operate and manage its project, but unlike concessions, its customer is usually the public partner, which buys the output and then supplies it to the consumer, becoming its main revenue stream.

**General analysis of the aggregated projects**

For the purposes of the analysis the Smart City Dimensions were sub-divided into Specific Fields, which are later explained in the analysis. The reason behind this is that there is a better understanding of the connection between the Financing Instruments and the different Smart City projects with IoT technology. On the other hand, the Financing Instruments, as mentioned before are divided in 3 categories (Public, Private and PPP Financing) since these are the sources of financing for any project. Public and PPP financing categories are subdivided according to the information gathered about the projects and to reflect in an understandable way the behavior of the investors of these projects. On the other hand, private financing is not sub-categorized, due to the fact that the projects analyzed and placed in this category are business projects and the information about the source of the investment is not public.

The category Public Financing was subdivided into projects that were financed by the city’s government and the ones that received financing from the National Government (partially or complete), including projects financed by the European Union. The reason behind this decision is that not all cities are open about the specific sources of financing about the projects they support, but do make public the fact that they are financing them.
Regarding PPP Financing, the category was divided into 3 sub-categories, taking into account the similarities between the types of contracts and the main sources of financing in each one. The sub categories are:

- Management and Operation & Maintenance Contract
- Lease and Affermage Contract
- Concession and BOT Contract

In the next section, a short analysis of the financing of Smart City projects with IoT technology will be presented, followed by the results of the analysis of the financing of each Smart City dimension and their specific fields.

**Number of Projects Analyzed**

![Graph 1. Number of projects analyzed divided into Smart City dimension.](image)

In the Graph 1 it is shown the number of Smart City projects using IoT technology found in the selected cities, organized between the 3 Smart City Dimensions analyzed. As seen in the graph, Smart Environment and Smart Mobility are the dimensions that hold most projects analyzed, 47% and 46% respectively; leaving only 7% of the projects in the Smart Living Dimension. This behavior is a result of the fact that most cities are investing in improving its mobility and environment first, because projects in these areas are meant to solve problems related to the reduction of energy consumption, use of renewable energy sources and overall decrease of the contamination of the environment, which are worldwide concerns, making them priorities amongst cities.
The other 3 Smart City dimensions (Smart Society, Smart Government and Smart Economy) although important to develop a Smart City, do not use the Internet of Things technologies to function, or at least not yet. Smart Society is fundamental for the creation of a Smart City, because projects and initiatives in this dimension are focused on the inclusion of the citizens to the new digital initiatives that are being implemented in the cities, showing them how to use them and educating them into the concept and purpose of the Smart City. Smart Government and Smart Economy are dimensions that are still in early stages compared to the others in terms of density of projects initiated and technology used in them.

Type of Financing amongst all projects

![Graph 2. Percentage of the type of financing implemented amongst all projects.](image)

In Graph 2 the percentage of each type of financing amongst the projects analyzed is shown, without regarding the Smart City Dimension, in order to provide a general overview about the behavior of both public and private sectors. Public Financing (City Financing and National Financing) accounts for 41% of the projects, while Private Financing accounts only for 14% of them, and finally PPPs account for 45%. From this information, it has been concluded that, in general, Smart City projects with IoT technology are mostly financed by both PPPs and Public Financing, which shows the commitment the public sector has with the Smart City movement.
The public sector is more willing to take on the financial risk of the uncertainty of the projects for the benefit of its citizens and, according to our findings; there is not a notable difference between the amount of projects financed solely by cities and the ones receiving financing from National government. On the other hand, the private sector rarely takes on this risk, financing only 14% of the Smart City projects researched in the 25 cities, because it usually is not a financially smart decision to invest in these types of projects, when the technologies are in such an early stage. PPPs are a different scenario, in which, depending on the interests of both parties (Public and Private), the terms of the contract are finalized and also the terms of the part both parties play in financing the project. Taking into account the description of the 3 categories of PPPs used in the analysis of the projects, it can be concluded that Leases and Affermage contracts are the most common PPPs so far in terms of Smart City Projects using IoT, since cities are currently the most interested in Smart City projects, but usually do not have the technologic know how or assets to develop them.

As seen in this Graph 2, the amount of projects financed by PPPs and Public Financing are very similar and both over 40% of the total projects, while Private Financing is rare. Besides the risk of the high uncertainty of the investment in these types of projects, another reason explaining the behavior of the private sector is that these projects are focused on the improvement of the public services provided to the citizens and thus, the city has more restrictions in terms of price policy and permissions to use public spaces.

In the following section, it will be analyzed the differences of this behavior between all the projects in general, the Smart City Dimensions, their Specific Fields and the reasons behind them.

**Analysis of Smart City Dimensions and Specific Fields**

The analysis was realized by aggregating the sample of 112 projects, all of which implement Internet of Things technologies, into 3 of the Smart City dimensions, which are the Smart Environment, Smart Living and Smart Mobility dimensions. After that, the projects were further sub categorized into specific fields of applications, which will be described later in more detail.
Smart Environment

This dimension holds a total of 53 of the 112 projects analyzed, which were aggregated in 4 specific fields, whose description and financing tools analysis are explained below.

- Environment Care
- Smart Lighting
- Smart Grid
- Smart Metering

Regarding the financing in this dimension, as seen in Graph 3, 57% of the projects were financed by PPPs, being the most common financing category in this dimension and almost doubling the amount of projects financed by the public sector (32%). The private sector holds only 11% of the projects analyzed, which provides no significant change compared to the financing of all the projects analyzed.

Graph 3. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Environment dimension.

Taking into account the information above and the characteristics of the projects in this dimension, it is concluded that PPPs are the most common and also most effective way of financing a project in Smart Environment. The behavior presented is caused by the fact that Smart Environment is the dimension in which all cities are trying to improve thanks to
the objectives established by most National governments around the globe in terms of countering the consequences of global warming and climate change. In addition, each city has different characteristics like weather, geography and infrastructure that make projects in this dimension difficult to replicate successfully projects from other cities, and because of this, the city needs to modify these projects or create new ones, leading to the need of including private companies in the development of these projects, not only for the financial support but also for their know how in terms of technology.

In terms of the specific financing tools used in the projects in this dimension, there was not a significant change in the behavior of the different types of PPPs in comparison to the analysis of all projects. On the other hand, there is a slight increase in the percentage of projects financed by the City compared to the ones financed by the National Government, unlike the behavior of the entire sample, in which these two types of financing contribute in nearly the same amount.

After describing the analysis for the Smart Environment dimensions as a whole, as previously established, a brief description of the 4 specific fields of application will be given, followed by a similar analysis of the financing used in this dimension for each field.

**Environment Care (18 Projects)**

Projects in this specific field are related to the improvement of the management of natural resources and the monitoring and control of solid waste. They are characterized by the use of smart sensors to measure environmental variables, like air and noise pollution, humidity, temperature; some sensors were created to measure the level of solid waste in garbage containers to improve the recollection routes of garbage trucks and other sensors to measure and pinpoint leaks in the water supply system, allowing a more accurate monitoring of the water network.

Regarding the analysis of the financing used in these projects, it can be seen in Graph 4, that as in the Smart Environment dimension, the main form of financing comes from PPPs, specially Leases and Affermage contracts, which show the big commitment the public sector has on projects in this field. On the other hand, private financing is still the less used and actually in comparison to the dimension, its contribution in terms of Smart City projects financed is lower.
The projects included in this field are characterized by switching the traditional bulbs for LED lights, installing sensors to measure the level of light outside and automatically adjust the light level of the bulbs to minimize the energy consuming providing an optimal streetlight service. Some projects include streetlights provided with motion sensors to turn off lights when there are not passengers or cars nearby and some streetlights can be remotely controlled and monitored by a central office of the service provider, allowing a better use of the maintenance resources and improving the service provided to the people.
As seen in Graph 5, the percentage of projects financed by private companies is 20%, which is higher than in the Smart Environment Dimension and in the whole sample of projects. The reason for this is that Electricity providers for the cities are usually private companies and projects in this field involve less uncertainty than in other fields of application. The technology used in most of the improvements to the Lighting in the city, such as LEDs and smart sensors, is already known to the owner of the company and projects of this type are replicable, in the sense that the technology used for improvements in this area has been tested already in some cities, thus lowering the uncertainty of the project, in addition to the financial benefit of LED lighting due to its high power efficiency.

Regarding public financing, there is a clear difference in the number of projects financed by the City and the ones receiving financing from the National Government. Projects related to Smart Lighting financed by the public sector are usually financed by the city, as shown in the results of the sample in which there are 4 times more City funded projects than the ones receiving National funding.

**Smart Grid (12 Projects)**

As its name implies the Smart Grid field includes the projects related with the changing or improving of the traditional electric grid or part of it into a Smart Grid, by integrating intelligent mechanisms that allow the companies to have access to the behavior and actions that the users have regarding the electricity used, to match the supply and demand of the grid in a more sustainable, economic and safe way. In these projects the electric grid is equipped with smart sensors and automated switches that allow a better control of the electric supply, matching the demand in the grid. These projects have big capital investment, because of the materials, the technology used and also because they tend to be large-scale projects. The main objective of a Smart Grid project should always be to supply the whole city with power from the newly created grid, thus requiring a lot investment, but also a lot of financial rewards when the grid is fully functional. There are cities that have opted to create a smaller grid in a neighborhood or a district as a sample to test whether or not a full Smart Grid is a viable investment or not, but the main goal is to supply electricity to the whole city with it.
Graph 6. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Grid.

Receiving financing from a PPP is the most common form of financing projects in this field (64% of projects of the sample in the field), which is more than twice as common than Public Financing (accounting for 27% of the projects in the field) and 7 times more used than Private Financing. By analyzing the information in Graph 6, it is clear that the distribution of the projects according to the financing they used has not a significant differentiation, in terms of the 3 main types of financing, in comparison to the distribution of the Smart Environment dimension. Nevertheless, the behavior inside PPPs and Public Financing did change.

Leases and Affermage contracts are the most common PPP used for financing a project in the entire sample of projects and also in the Smart Environment dimension, but in this field the most common one is a concession or a BOT contract. The reason behind this is that Smart Grid programs are very lucrative in the long-term for companies that supply electricity for the cities, because of the improvement in the control of the electric grid and the higher efficiency in meeting the demand. By signing a concession or BOT contract, the companies have more control over the decisions in the creation of the project, they take most of the earnings themselves and since electricity companies usually have a big pool of capital, they can take the risk of the investment.

Regarding Public Financing, projects that received National funding were twice as common as those who were financed entirely by the city in the sample of this field. Due to the large-scale of these projects, the investment for them is high and cities usually don’t
have the capital to finance them, so they make a partnership with a private organization or pitch the project to the National Government in order to receive financial support from them.

**Smart Metering (8 projects)**

This field is closely related to the Smart Grid field, consisting in projects that implement sensors to allow the measurement of the electric consumption, showing through digital screens or online platforms said consumption to promote a better behavior from the consumers. However, unlike Smart Grid projects, these projects require less capital investment but there is more resistance from the government and the citizens. This is because, although the cost of the installation of smart sensors in a household is low, some of the population of many cities is still reluctant to having sensors all over the house, feeling that this may violate their privacy and thus, they resist the change. Many Smart metering projects started with neighborhoods too, such as two projects from Amsterdam, in which a small community accepted to have the smart sensors installed in their houses and in little time realized the savings in terms of electricity they had, just from being able to see how much electricity was consumed by many of their electro domestic items in their household.

**Graph 7.** Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Metering.
The Smart Metering field holds the smallest amount of projects within the Smart Environment dimension sample, even though there are many projects developed and being developed in the field, but not all of them use IoT technology to provide the information or to act upon the information gathered, which is why the amount in the sample is low.

Regarding the distribution of the projects according to the financing used, it is very similar to the distribution shown in Graph 3 for the entire Smart Environment dimension, as it can be seen in Graph 7. PPPs are the most common form of financing projects in this field, followed by Public Financing and then by Private Financing. There is an important difference inside the PPP group and that is that there are more projects that used Management, Operation and Maintenance contracts than Concessions and BOTs. It has been concluded from the information about the projects that one of the main reasons for this behavior is that cities prefer to handle the information from these Smart Meters themselves and since the investment for these projects is not very high, they prefer Management and Operation contracts over concessions and BOT contracts.

Smart Living

This dimension has a total of only 8 of the 112 projects analyzed, holding the smallest amount of projects within the entire sample. Given the small number of projects found for this dimension and the fact that all the projects seek to improve the quality of life of the citizens, specific fields for this dimension were not made and all the projects were aggregated in the Smart Living dimension. These projects focus on improving the security, the surroundings and infrastructure of the city, and implementing new services allowing a better inclusion of all citizens. In terms of the financing in this dimension, 4 of the 8 projects were financed by a Public-Private Partnership, while 3 projects were financed by the public sector and only 1 project by the private sector, following the general distribution of the projects in the different financing categories within the entire sample, as shown in Graph 2.

Regarding the distribution of the financing tools within the financing categories the distribution for the Smart Living dimension differs with the one showed in Graph 2 significantly. The biggest changes showed are that in the Public Financing category all
projects were supported by the National Government and that in the PPP category the most common financing tool are Concessions and BOT contracts and not Leases and Affermage contracts, which are the preferred financing tools in general within the whole sample of projects.

**Smart Living**

![Graph 8. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Living dimension.]

Other aspects worth to mention is that the projects financed by the public sector, in this case only by the National Government, were focused on using IoT technologies to increase the security of the citizens and to improve the methods to share information in the cities and between cities. This behavior is caused by the fact that in order to accomplish that, there needs to be a coordinating partner, so these projects are coordinated by the National government.

**Smart Mobility**

This dimension has the highest number of projects within the sample, holding a total of 51 of the 112 projects analyzed, which were aggregated in 3 specific fields, whose descriptions and financing tools analysis are explained later on.

- Smart Parking
- Smart Traffic
• Smart Vehicles
The large amount of projects found for this dimension was expected, taking into account that the increase in traffic congestion and the pollution caused from this is one of the major problems in most cities around the world. These cities are currently tackling these problems by searching for alternative options on how the transportation systems work within the city and by trying to salvage and save the resources that are still useful. Their main goal is to decrease the negative impacts caused by the congestions without diminishing the quality of the services provided to the citizens.

Graph 9. Percentage of the type of financing implemented amongst all the projects aggregated in the Smart Mobility dimension.

Regarding the financing in this dimension, as seen in Graph 9, 50% of the projects in this dimension were financed by the public sector, with a balanced percentage for both types of financing in this category, but with a slightly high percentage of projects financed by the National Government, which is the same distribution found for all the sample of projects, seen in Graph 2. This leaves the other 50% of the projects in this dimension distributed between the PPPs, holding 32% of the projects, and the private sector with the final 18%, which is a rather high percentage for private financing, taking into account that the percentage of projects financed by the private sector in the other two dimensions analyzed
was very small, in comparison with the amount of projects belonging to the other financing categories.

The Smart Mobility dimension is the first dimension studied that has the public sector as the most common financing category, with National financing as the most common financing tool. This behavior shows the importance that the government gives to Smart Mobility and that it is a priority for them to invest in it to reduce the CO2 emissions caused by poor traffic control. Regarding the PPPs, the most common financing tool used in this category is Leases and Affermage contracts, while the other two tools (Management, Operation and Maintenance contracts, and Concession and BOT contracts) are tied up in its use, showing less Concession contracts compared to the analysis of all the projects. This is caused by the fact that the government usually does not want to give too much control over transportation and parking to the private partner. Transportation is one of the main services provided for the citizens and the government must be sure that the measures taken to improve the mobility in the city do not have negative repercussions in the service provided and that the price of the service does not change drastically.

As previously established, now it will be given a brief description and a similar analysis of the financing used for the 3 specific fields of application for the Smart Mobility dimension.

*Smart Parking (10 projects)*

The projects in this specific field are focused on the improvement of the parking experience within the cities, by facilitating the way drivers find parking spaces through sensors embedded into the streets, into spaces designated as parking spots or in the lamp posts, which send a signal of the state of vacancy to apps and web portals that the users can use to find the nearest parking spot, reducing the time and pollution each driver wastes in finding parking. In addition, these projects seek to improve how the government manage these spaces, through the improvement of the parking meters, creating easier ways to make the payments, with the help of apps, GPS technology, sensors and other smart technologies.
This specific field shows a rather different distribution of the financing categories seen so far, as can be seeing in Graph 10, because of the high number of projects financed by the public and private sectors, leaving the PPPs, which have been the most common form of financing so far, holding a quite shy number of projects. This distribution of the projects can be explained by the fact that according to the information found of the projects, the Smart Parking projects have to be heavily monitored by the public sector because, in general, the parking spots distributed in the city are property of the Government, which want to improve the service provided to the citizens but preventing the private sector to have control over the price of the parking fares or the availability of said parking spaces. On the other hand, the projects financed by the private sector serve mainly as a bridge between people looking for parking spaces and the people who own parking spaces and rent them; this process is possible through an app and smart sensors in the parking spots.

**Smart Traffic (30 projects)**

In this field, the projects are focused on traffic management, emergency response systems and traffic information. This means that these projects seek to give more control and monitoring capacity to the transportation offices, improving the flow of traffic within the city, giving more information to the drivers in order to prevent accidents and traffic congestion. The tools currently used to accomplish these objectives are electronic signs, mobile apps, GPS tracking, smart traffic lights, among others, which are connected to an operations'
center, which handles the information gathered from each of the tools. Some of these tools, such as the smart traffic lights and the mobile apps, are programmed to automatically perform tasks according to the information gathered, while others gather real-time information and send notifications to the operations’ center and they decide which action should be done. In addition, there are projects that target the response time of emergency vehicles like fire trucks, ambulances and police vehicles; by using the smart traffic lights and the information gathered from the sensors throughout a city to give priority to this type of vehicles, the city can reduce their response time and provide a better service to the population in the city. These new systems also gather information from buses, bus stops, meters, tolls, cars, taxis and devices in the city, with the implementation of smart sensors. This information is then shared with the citizens through apps and online portals with the purpose of saving time and improving the commuting efficiency, improving the routes of public transportation and thus, decreasing their costs and reducing the environmental impact of these.

Regarding the analysis of the financing used in these projects, it can be seen in Graph 11 that the projects in this field show a similar distribution through the 3 financing categories and within them, as the one showed for the Smart Mobility dimension (See Graph 9). 50% of the projects in this field were financed entirely by the public sector, and 75% of those were received financing from the National government. This behavior corresponds to the fact that Smart Traffic is top priority in the Smart mobility dimension, as seen in the sample, in which 19 of the 22 cities that have projects in the Smart Mobility dimension...
have at least one project in the field of Smart Traffic. Projects in this field are usually large scale, needing a lot of investment and Know How in smart technologies, which is a reason why the National Government supports them so strongly.

Regarding the PPPs, the distribution of the projects does not change significantly compared to the Smart Mobility dimension, being Leases and Affermage contracts as the most common PPP in this field. Private financing is the least used type of financing in this field too, accounting only for 13% of the sample of projects in this field.

**Smart Vehicles (11 projects)**

The projects aggregated in this specific field are related to the use of alternative forms of transportation to change the way people move in the city, by promoting the use of different types of transportation, such as the different types of public vehicles (bus, taxi, among others), private vehicles and bicycles. The main objective is to mobilize in a more sustainable way, by prioritizing the use of car-pooling or car sharing services, eco-friendly transportation (electric or hybrid cars) and non-motorized transportation (cycling) without affecting negatively the mobility in the city. Projects in this field usually don’t need a lot of capital investment in the beginning, because they usually focus their efforts in improving one of these types of transportation and create great ways to show the people that these means of transportation are just as good in terms of time and way better in terms of sustainability and health.

**Smart Vehicles**

![Pie chart showing the percentage of financing types for Smart Vehicles projects.]

**Graph 12. Percentage of the type of financing implemented amongst all the projects aggregated in the specific field of Smart Vehicle.**
The Smart Vehicles field shows the most even distribution of projects between the 3 financing categories, as seen in Graph 12. As in the Smart Mobility dimension, most of the projects in this field were financed by the public sector. However, in this case, there is a variation in the distribution within the public financing category, which is that the city financed most of the projects instead of the National Government. The reason behind this is that projects in this field are not large scale and they do not need large amounts of capital to start, which is why the city can finance them without the help of the National government. Both PPPs and private financing hold the same amount of projects in this field. The private sector has a rather high percentage of projects within the field, due to the fact that car-sharing services have been very successful and profitable in many cities and this makes the option of financing the entire project more appealing for companies in this sector. Regarding the PPPs, it can be seen in Graph 12, the field shows an even distribution of the projects between the 3 financing tools that can be implemented but a low percentage compared to other fields or dimensions in the study. The scale of the projects, the type of technology used and the lower amount of investment compared to the other fields make projects in this field viable to be financed by an organization (public or private), which makes the option of doing a partnership less interesting for the organizations that want to invest and/or create a project in the field.
Chapter 4

Conclusion

The Smart City paradigm started being mainly supported by leading technology companies who searched to promote and test the use of new devices and mechanisms developed by them to improve traditional systems that were thought to be top of the line only a few years back. Nowadays, cities and National governments have seen the benefits that these new technologies can produce in terms of the improvement in the services provided to the citizens, as well as in terms of monetary savings in the maintenance and use of the services, and finally, the huge positive impact that Smart City projects show in terms of environmental care, which after the global concern about climate change, became the primal subject of interest in the world, increasing the number of initiatives, projects and investments regarding the Smart City in several cities worldwide.

Regarding the paradigm of the Smart City linked to the technologies under the Internet of Things umbrella; the number of projects is still low but with a tendency to increase in the near future, thanks to the positive results obtained with the projects built so far and to the improvement that many organizations and partnerships are making with IoT technologies for Smart City projects. These technologies are cost effective, give more information about the surrounding area and, if used accordingly, can contribute to the improvement of the service provided by the city without increasing the cost in a significant manner. The risk of most Smart City projects with IoT technology has shifted through time; at first it was related to whether or not the technology needed for the project to be successful was actually possible to create, develop and use, but now that IoT technology is more reliable, this risk is mostly related to the value of the information gathered by smart sensors and other IoT technology and the actions that can be executed with regards to that information. Regardless of this risk, there are still many technology companies creating new technology and devices, and by creating partnerships with cities, they have test beds for their technology and the risk is lower for them, giving a boost to the creation of new ways to make the cities in the world a better place to live.
One of the most important aspects in the development of Smart City projects with IoT technology is the financing needed to turn the idea of the project into action and make it a reality. The perceived financial risk linked to these types of projects has been diminished by the quantity of successful projects created by forerunner cities such as Barcelona, Amsterdam and Copenhagen and this has led to an increase in the parties interested in investing in Smart City projects and the use of IoT technology. In spite of this, there is still difficulty in finding financing for many projects and it is important to understand which are the best sources of financing for the different types of projects, since according to the findings in this analysis, the Smart City dimension and the specific field have a connection to the likelihood of finding financing from the different sources.

From the projects selected from the 25 cities in the sample it was established that all projects were in 3 Smart City dimensions (Smart Environment, Smart Mobility and Smart Living), and through the research it was found that it was caused by 2 factors. First, the dimensions Smart Government, Smart Economy and Smart Society are just at a starting stage, meaning that there are very few projects in these dimensions, because cities and big technology companies focus most of their efforts and investment in the Smart Mobility, Smart Environment and Smart Living dimensions. The second reason is that from the few projects found in the dimensions not included in the analysis, the majority did not use IoT technology to accomplish their goals and the amount was too small to make an analysis of the financing tools used to finance them.

The dimensions Smart Environment and Smart Mobility hold approximately 93% of the projects analyzed in this study, showing the big commitment cities have with finding ways to diminish the consequences of global warming and to achieve sustainability in the cities. As mentioned before in the analysis, projects in these dimensions have a higher short and medium term impact on the problematic related to global warming and climate change, which is the main reason that cities focus their investment and efforts in them. In addition, thanks to the interest of many cities worldwide about projects in this area, many technology companies, universities and research centers have also focused their interest in them, leaving the other 4 dimensions with little manpower and investment. Nevertheless, there has been more projects in the Smart Living dimension than in the remaining 3, and among these projects, an important portion uses IoT technology to achieve their goals.
In general, the study shows the big commitment of the public sector to promote and develop Smart City projects, regardless of the financial risk linked to the uncertainty that these kind of projects bear, but knowing the benefits that these improvements can bring to the city in terms of reduction of the city’s expenses, increase of the quality of life of the population and the increase in the competitiveness of the city in the international eye. Regarding the public sector, which financed 41% of the projects by itself, the number of projects in the entire sample financed by the National Government and those financed by the cities were almost the same, with more projects financed by the National Government than by the cities, but the difference is not significant to make the assumption that more projects are financed by the National Government than by cities. Nevertheless, it was found that projects that had a larger scale and required more investment were financed in their majority by the National Government.

The private sector has a different approach to Smart City projects than the Public sector. Organizations in this sector have different objectives with the creation of these projects, from which the most common are creation of revenues, an expansion of the market share in a specific sector or the creation of technology that creates a new market or blue ocean. Due to this approach, the private sector takes fewer risks in the development of Smart City projects with IoT technology, and only 14% of the projects analyzed were financed entirely by the private sector, unlike the public sector that financed 41% of them.

Smart City projects that use IoT technology are complex projects; they require the Know How to develop new technology or upgrade existing one to accomplish new tasks, they also require additional permits from the city to be able to move forward with the projects and they require the financing needed to buy the initial assets and to pay the manpower and execution costs during the life of the project. For these reasons, 45% of the projects analyzed in this study were financed by Public Private Partnerships (PPPs). Amongst these partnerships, the most common contract used in the PPPs category were the Leases and Affermage contracts, financing 19% of the all the projects analyzed, since cities’ governments are currently the most interested parties in developing Smart City projects, and through agreements like these they can have access to the Know How needed to build the projects, while also protecting themselves from giving too much power over the project to the private sector. Interestingly, Concessions and BOT contracts, in which the private sector has more freedom in terms of how to pursue the development of the projects, financed 15% of the projects analyzed, not falling far behind from Leases and
Affermage contracts. On the other hand, Management, Operation and Maintenance contracts only financed 11% of the projects analyzed and were the least used financing tool within the study.

Regarding the findings for each of the Smart City dimension studied, Smart Environment and Smart Living have a similar distribution of projects among the financing groups. In terms of financing for the projects aggregated in the Smart Environment dimension the main financing group used was Public-Private Partnerships, which accounted for 57% of all projects in the dimension, almost doubling the amount of projects financed by the public sector (32% of the projects in the dimension) and at last, the private sector financed only 11% of the projects in the dimension. The financing in the 4 specific fields within the Smart Environment dimension (Environment Care, Smart Lighting, Smart Grid and Smart Metering), have a similar distribution concerning the 3 main financing groups, but there are notable differences among the specific forms of financing used in each field. In the Smart Lighting field 20% of the projects were financed by the private sector, which is the highest percentage in the dimension. The Smart Grid and Smart Metering fields, although really related, have a very different distribution of projects among the types of PPP, due to the scale of the projects in the fields and the technology used in them. The Smart Grid field has the highest amount of projects financed by Concessions and BOT contracts (28% within the field), but in the Smart Metering field only 11% of the projects were financed through Concessions and BOT contracts and Management, Operation and Maintenance contracts financed 22%, which is the least common PPP used in all the projects in the sample.

In the Smart Living dimension the distribution nearly repeats itself by having the large amount of projects within the PPP category (51%) followed by projects financed by the public sector (37%) and the private sector with 12%, but with the difference is that in this dimension the most common type of PPP used was Concessions and BOT contracts, instead of the Lease and Affermage contracts most common used in the Smart Environment dimension, and that in the public financing category all the projects were financed by the National Government. On the other hand, in the Smart Mobility dimension the majority of the projects were financed by the public sector (50% of the projects in the dimension), without a notable difference between the projects financed by the City and those financed by the National Government. Interestingly, PPPs only financed 32% of the projects in the dimension and the private sector financed 18% of the projects, which is the
highest percentage of private financing across the 3 dimensions. This behavior in which the majority of the projects are financed with public resources can be seen in all 3 specific fields within the Smart Mobility dimension (Smart Parking, Smart Traffic and Smart Vehicles). In the Smart Parking and Smart Vehicles fields the projects financed by the private sector and PPPs finance the same amount of projects, but are significantly less than the projects financed by the public sector; this behavior sets them apart from the rest of the specific fields in the study.

To sum up it can be said that in general the number of Smart City projects that use Internet of Things technologies is increasing rapidly within the Smart Environment and Smart Mobility dimensions, followed by the ones in the Smart Living dimension that is in an early stage in comparison with the other two. And that these projects in terms of financing methods favor the Public-Private Partnerships, especially those that give a major part of the risk and control of the profits to the public partner, leaving the private partner in charge of providing the Know How in technology and the development of the projects and with less financial risk. It has been concluded that the projects within the Smart Mobility dimensions are the ones in which both public and private sector feel more comfortable to create and finance by themselves, leading to a rather small amount of projects financed by PPPs, but it is advisable to look for financing in the public sector, because the private sector is more reluctant to invest than the government of the city. On the other hand, projects in the Smart Environment and the Smart Living dimensions are financed mostly by PPPs due to the higher uncertainty of the technology and the amount of regulations and environmental laws.
Appendix

Case Study: Smart City Rio de Janeiro

The Operation Center of Rio de Janeiro or Centro de Operações Prefetura do Rio de Janeiro (COR), is one of the world’s most ambitious integrated urban command center that has been developed yet. This advanced operation center was created in 2011 after the catastrophic event that brought Rio de Janeiro to a standstill caused by heavy rainfall, floods and mudslides in 2010. At first, the purpose of the operation center was to counter and prevent disasters like the one of 2010, and to ensure that the city had the proper tools to manage these kind of emergencies, but taking a step further the operation center was developed to allow city officials to manage any kind of events or disruptions and city daily activities, like traffic, public transportation and security of the citizens, by creating, inside the COR initiative, Smart City projects tackling these issues. The idea is that the operation center will evolve continuously to integrate new features, more information and more city departments. Rio de Janeiro is revitalizing itself, looking to transform the city into a Smart City, improving its transportation system, its infrastructure and in general its way to manage any kind of problem that can arise in a city.

Since 2009, the Rio de Janeiro City Government, led by the mayor Eduardo da Costa Paes, is working to overcome financial restrictions by introducing innovative ideas and the management style of the private sector, as well to remove unnecessary obstacles and formalities to the participation of private agents in the management of public resources. Changes in regulation were fostered so that Public-Private Partnerships (PPP) could be created and managed in a proactive, flexible way, to make it easier to tackle the economic, social, urban and operational challenges stemming from the organization of the Football World Cup (2014) and the coming Olympic Games (2016). Proof of the success of this initiatives is that in 2013, the private participation in the resources managed by the Municipal Government of Rio de Janeiro amounted to 35% of the total.
In 2010, the COR was developed thanks to a Public-Private Partnership between the city of Rio de Janeiro and multiple private agents, but primarily it was designed and created by IBM Brazil, after an agreement signed between them and the city government of Rio de Janeiro, with an initial cost of R$14m (14m reales), but the work is still ongoing. Other partners engaged in the development of the Operation Center, both in terms of technological and financial support, are Cisco, Oracle, Cyrela Facilities, Malwee, Oi and Samsung.

The COR is the main investment Rio de Janeiro has made in terms of Smart technology in all time. The Center is located in Cidade Nova and it integrates more than 30 organizations, both in the local Government and in the private sector, with the purpose of providing assistance in the decision-making process, by sharing information between them, related to management and monitoring of emergencies, natural disasters and daily activities, to improve the city’s safety and responsiveness. The COR is the first center that integrates all the stages of a crisis management situation, allowing to predict, mitigate and prepare to respond to any kind of event or disaster and to register data from the situations to be used in future similar situations.

One special feature of the Operation Center is its high resolution weather forecasting and hydrological modeling system or PMAR, developed by IBM Research scientists as part of the agreement with the city of Rio de Janeiro, which predicts heavy rainfalls up to 48 hours in advance allowing that the city officials can warn the citizens of possible floods or landslides and organize preventive activities or in case or incidents coordinate a quickly emergency response. Currently, the system can predict rainfalls and anticipate possible flash floods and mudslides, and the city has begun to evaluate the effects of weather on other situations in the city, like traffic and on the supply of electricity.

The COR also shared the information that is gathered with the citizens of Rio through an official website, Facebook and Twitter feeds and other applications, where the citizens can access daily updates of real time information on weather conditions, traffic jams, pollution, crime rate and recommendations for alternative routes during large public events or rush hour. In the COR there are also present of mass media companies, radio and TV stations that help to spread the updates and to warn citizens in case of emergency. To date, the COR has become a platform to guide smart city investments and foster innovation in urban management.
Case Study: Smart City Barcelona

Barcelona, the second largest municipality of Spain, is one of the most fascinating and cosmopolitan cities in Europe; and for some years now, it has gone through an urban, economic and social revitalization, applying innovative solutions to managing its services and resources to improve the environment of the city and hence the quality of life and work for its citizens. The innovation’s spirit and the drive to improve as a city that has always characterized Barcelona have led it to become a pioneer in the Smart City movement and thanks to its transversal strategy, with a long-term vision of urban development, Barcelona is considered to be the first Smart City in Spain and in the world, according to IDC Corporate US (2012) and to Juniper Research (2015), respectively, and the fourth in Europe, according to Boyd Cohen (2013).

Barcelona is working to become a self-sufficient city, innovative, open and inclusive, with productive neighborhoods, within a connected and zero-emission metropolis, to ensure that the city’s residents benefit from a better quality of life and economic growth. To create this vision Barcelona, in collaboration with entrepreneurs, companies and organizations committed to public innovation and new technologies, is merging urban planning, sustainability and ICTs in projects that coverts all six of the Smart City dimensions to positively affect the competitiveness, innovation and job creation in the city. In the last years, Barcelona has developed several pilot projects to install sensors throughout the city and created platforms to share information with citizens, city leaders and businesses.

The Smart City movement in Barcelona, started to receive more attention in 2011, when the current mayor was elected, and his administration immediately began implementing a comprehensive Barcelona Smart City program, called “Smart City Barcelona” structured by the city government in 2012, aimed to efficiently provide city services at multiple levels to all citizens and to address sustainability and environmental concerns based on the use of ICTs. The emphasis on developing Barcelona’s Smart City capabilities placed by the mayor and his support has been key to the success of Smart City Barcelona, because it has helped in uniting the different departments and cut through the city’s bureaucracy, speeding Barcelona’s ability to develop and find financing for its Smart City projects and helping in gaining the support of the public, allowing a faster adaptation to new
technologies. Another key decision made in Barcelona’s Smart City strategy was the establishment of a Smart City Strategy team within the mayor’s office in charge of promoting and coordinating Smart City application development throughout the city organization, which has also helped in a smoother development of the projects. Furthermore, the city of Barcelona is currently using an open tender procurement process to identify a developer to build a “City OS”, intended as an operating system that will sit atop the city’s established network of sensor technology to gather and analyze data that is collected across the network. City officials envision this “City OS” as an open platform working across the various specific smart technology projects operating in the city.

In the Smart City Barcelona strategy, Barcelona had to adapt to deal with large multinational companies, which were not accustomed to work at a municipal level, with the purpose of developing Barcelona’s Smart City capabilities by partnering with key technology companies. As stated by Ms. Julia Lopez, coordinator of Smart City strategy for the city of Barcelona and coordinator of the ICT International Office for Urban Habitat of Barcelona, the city of Barcelona can’t afford to do all the developments planned or needed by the city, so it is crucial to follow a strong and planned Public-Private Partnership approach. The city of Barcelona while doing the Public-Private Partnership has been careful to ensure that the system architecture, made by the city contracting with technology companies, remains open and not linked to proprietary technology. This methodology has led to funding for new, sustainable business models, to ensure companies a way to gain profit, without relying just on added revenue coming from future software upgrades, but also because companies have a successful platform they can market and sell in other municipalities.

In terms of Smart City projects where Internet of Things technologies are implemented, Barcelona City has developed quite a few initiatives, centered in the Smart Environment, Smart Mobility and Smart Living dimensions. Some of the projects that are already being implemented and used in the city of Barcelona are: the fiber optic network throughout the city (acting as a backbone for all the Smart technology projects), the Pneumatic waste management system, Smart irrigation system for parks and green areas, Smart street lighting, Environment Smart sensors, Smart Sensors in Waste Containers, Smart Parking spaces, Bi-articulated bus, Orthogonal Bus Lines, Smart Bicing, Smart Electrical Vehicle
charging, Smart Traffic lights for the blind and Fire Brigade vehicles and Smart sensors implemented in beaches and parks to improve the management of them.

All of the above mentioned projects are completed projects that support the improvement of public services within the City of Barcelona causing benefits in the quality of life of Barcelona’s citizens, showing the commitment to promote innovative initiatives that make Barcelona a best practice in Smart Cities. 7 out of the 10 projects studied in Barcelona are being funded by Public-Private Partnerships with the city of Barcelona and multiple companies, and have been coordinated by the City Council and the companies Abertis, Cisco and Indra, with the participation of companies such as, Libelium, Urbiotica, Worldsensing or Zolertia, among others. Regarding the remaining 3 projects, 2 of them are financed entirely by the City and just one is financed by a private entity.

Case Study: Smart City Boston

Boston is one of the metropolitan centers of the United States of America and is a city traditionally known for its famous universities and research centers, like the MIT (Massachusetts Institute of Technology), where new technologies to gather and visualize data are being developed thanks to the Senseable Cities Lab program. Currently, Boston has started to invest time and money of their budget in laying the groundwork and it can be considered as a best practice for the Smart City, thanks to its multidisciplinary approach in various Smart City initiatives, which in the last few years have transformed the city of Boston in an innovation hub and living lab, where the government and private companies can experience with new technologies to improve the city services.

The city of Boston has used the new technologies to improve the infrastructure in the city, with projects like Street Bump. It has also tried to improve the education, through projects like Boston One Card, Where My School Bus and Classtalk. And lastly it’s working to involve its citizens in a more active way in the decision making process of the city, creating a better collaboration between the government and the citizens of Boston, to keep Boston’s programs based in what the citizens want, and not just what City Hall decides. Some projects developed for this purpose are Citizens Connect, Community PlanIt and Innovation District. The vision for Smart City Boston is to interconnect its isolated systems to make them more robust by merging functions like intelligent traffic systems, safety
surveillance and environmental monitoring with sensors into one flow of data that turns the city into a proactive and responsive system.

Most of these Smart City projects are being developed thanks to public initiatives, like the MONUM project (Boston’s Mayor’s Office of New Urban Mechanics project) that search for ways to improve the quality of the city’s services and the financing from the National Science Foundation (NSF) with the purpose of implementing a new urban management system. Although, Boston’s government is being very active in planning, implementing and promoting Smart City initiatives; it’s well known to the public entities that partnerships with private companies are essential to transform the city into a Smart City, as said by Bill Oates, the Boston’s chief information officer. Because any government is not in a position to build sensors and networking software, any more than it can build its own buses, subways or public buildings, that’s why the Public-Private Partnerships are required. But, as Mr. Oates has also stated, none of Boston’s projects yet have required letting a company control city data, and even if the city builds closer partnerships with private firms there will be limits on how to use the technologies to improve the city’s services and in what degree the technology company will have control on the solution implemented, because even though the city needs the technology to make their vision work, their main objective is to improve their services and thus, the quality of life of its citizens. In order to do so, the solutions implemented must be focused on achieving this goal, leading the city to withhold the control over the solution developed.

As a result of the study, it was found that Boston is a peculiar case in terms of financing Smart City projects, since from the 10 projects analyzed in the study, 5 of them are financed by Public funds, and only 1 of those is supported by the National Government. As mentioned in the General Analysis of the 112 projects, usually most Smart City projects are funded by PPPs and that is the case for most cities, but thanks to the commitment of the city to the Smart City idea and the restriction of city data to companies, these projects are mostly supported and funded by the city of Boston. From the 5 remaining projects, 1 of them is funded by private funds and 4 by PPPs, 2 of those being funded by Management/Operation Contracts, in which there are more restrictions to the private partners than the other 2 categories.

One initiative, led by the Boston Transportation Department and supported by the MONUM is the Boston’s Complete Streets Strategy, which has as a main goal to ensure that
Boston’s streets are a greener, smarter and that they have more multimodal transportation network throughout the city and also great public spaces. It embraces innovation to address climate change and promote healthy living, by supporting the City’s sustainability initiative: Greenovate Boston, an initiative that encourages the citizens of Boston to reduce the Boston’s carbon emissions. During the development of this initiative, key city agencies in Boston have been meeting with some of the most innovative experts in the United States of America, in a collaboration to develop new street design guidelines and implement projects informed with the new Complete Streets approach.

While many cities are facing big budget deficits and financing new initiatives is a challenge, the city of Boston has managed to finance a number of energy efficiency initiatives by adopting new ways of communicating between the people who are in charge of capital expenditures and the people in charge of operating budgets. For example, as said by Todd Isherwood, an energy project manager for the city of Boston, the city of Boston was able to free funds from the capital budget for several efficiency upgrades, thanks to a series of demonstrations where it was proved that a building efficiency project reduced operating budgets and that an upgrade from traditional bulbs to LEDs in the streetlights accounts to substantial savings.
Bibliography


ANCI. (2013). VADEMECUM per la città intelligente. Osservatorio Nazionale Smart City.


Politecnico di Milano
Rafael Albor
Rina De Vuono


Mohammadian, K., & et al. (2014). *Civil Engineering and Urban Planning III*. CRC Press.


Venkataramakrishnan, R. (2015, May 01). *Everything you wanted to know about Narendra Modi’s 100 smart cities*. Retrieved June 8, 2015, from Scroll.in:
http://scroll.in/article/724297/everything-you-wanted-to-know-about-narendra-modis-100-smart-cities


