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ICTs for Smart Cities.

Categories of innovative urban FM services and proposal of indicators of smartness.

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Abstract

This study deals with the topic of smart services as applications of the Information and Communication Technology (ICT) in the smart city context. In particular, it is aimed at analyzing both the categories of urban innovative ICT-based services and the indicators systems of certain smart city rankings so as to promote a better integration of these two elements.

There are three main question behind this dissertation. First, considering that ICT is an important element for the development of smart cities and innovative ICT-based services are its direct applications, to what degree smart city rankings take the provision of these services into account? Second, do their indicators of smartness take the provision of this services into account? Third, are the currently available smart service categories facilitating the creation of systems of indicators of smartness which take into account the provision of smart services?

The purpose of this study is to address these questions by proposing possible solutions, in hopes of being a useful input for future research.

Thus, the objectives of this study are: 1) to propose service categories aimed at facilitating the development of systems of indicators of smart city rankings focused on the provision of innovative ICT-based services, 2) to integrate the smart city rankings examined by proposing a list of indicators of smartness based on the provision of these services.

This dissertation consists of two parts, divided respectively into two and three chapters. The first part shows to the reader why ICT is so important for the development of smart cities. It discusses also the importance of smart city rankings and describes their systems of indicators. The second part instead answers to the three questions raised in this abstract.

The first chapter is meant to define the smart city context and to explain its relationship with ICTs and, in particular, with the concepts of Internet of Things and Big Data. The second one illustrates some important smart city rankings, reporting their findings, describing their systems of indicators and comparing them on the basis of the relative importance of the provision of smart services for each of them.

The third chapter shows the link between ICTs and urban smart services, both UFM and not-UFM services, and proposes new smart service categories and a list of innovative ICT-based services which can be found in smart cities, based on standards and real case studies. The

fourth performs a check of the validity of the proposal of the previous chapter by operating a qualitative mapping of innovative services on a sample of Italian cities.

Finally, the last chapter proposes a list of indicators of smartness, based on the categories and on the smart services proposed and listed in the third chapter. This proposal is aimed at suggesting a possible integration of the examined city rankings in order to increase the relative importance of the provision of innovative ICT-based services in their systems of indicators.

Keywords: smart city, ICT, IoT, UFM, big data, service categories, smart services, innovative services, ICT-based services, smart city ranking, indicators of smartness

Sommario

Questo lavoro affronta il tema dei servizi innovativi come applicazioni delle Tecnologie dell'Informazione e della Comunicazione (ICT) nell'ambito della smart city. In particolare, esso si prefigge lo scopo di prendere in analisi le categorie di servizi innovativi urbani basati sulle ICTs e i sistemi di indicatori di alcuni smart city rankings al fine di promuovere una migliore integrazione tra questi due elementi.

Si è tratto spunto principalmente da tre interrogativi. In primo luogo, considerando che la ICT è un elemento fondamentale per lo sviluppo delle città smart e che essa trova vasta applicazione nei servizi smart, in che misura la dotazione di tali servizi innovativi viene presa in considerazione dai ranking delle smart cities? In secondo luogo, i sistemi di indicatori di smartness di detti rankings danno risalto all'offerta di servizi innovativi basati sulle ICTs? Ed infine, le categorie per la classificazione dei servizi smart attualmente utilizzate sono funzionali alla creazione di sistemi di indicatori di smartness che diano rilievo alla dotazione di servizi smart di ciascuna città?

Lo scopo di questa tesi è perciò quello di occuparsi di tali problematiche e di proporre possibili soluzioni, nella speranza di poter rappresentare un utile contributo per la futura ricerca in questo settore.

Perciò gli obiettivi sono: 1) proporre categorie per la classificazione dei servizi smart funzionali alla creazione di sistemi di indicatori di smartness che diano rilievo alla dotazione di servizi innovativi basati sulle ICTs, 2) integrare gli smart city rankings che verranno proposti proponendo una lista di indicatori di smartness basata sull'offerta di servizi smart in ciascuna città.

La tesi è divisa in due parti, composte rispettivamente da due e tre capitoli. La prima parte è volta a dimostrare al lettore l'importanza delle ICTs per lo sviluppo di una smart city e l'importanza degli smart city rankings nel contesto attuale, descrivendo inoltre i loro indicatori di smartness. La seconda parte, invece, è finalizzata a trovare una soluzione agli interrogativi di cui sopra.

Il primo capitolo, in particolare, è dedicato alla definizione del concetto di smart city e della sua relazione con le ICTs, soffermandosi soprattutto sui concetti di Internet of Things (IoT) e Big Data. Il secondo capitolo illustra alcuni importanti smart city rankings, riporta le loro conclusioni, descrive i loro indicatori di smartness e infine li compara sulla base

dell’importanza che i loro indicatori conferiscono alla dotazione di servizi smart di ciascuna città.
Il terzo capitolo è dedicato ai servizi smart, siano essi servizi di Urban Facility Management (UFM) o meno. Esso propone nuove categorie per la classificazione dei servizi smart e presenta poi un elenco di tali servizi urbani innovativi basato sull’analisi di standard e di casi studies. Il quarto capitolo ha invece lo scopo di verificare la bontà della proposta del capitolo precedente effettuando una mappatura qualitativa dei servizi innovativi su un campione di città italiane.
Infine, l’ultimo capitolo propone una lista di indicatori di smartness basata sulle categorie e sui servizi innovativi proposti e riportati nel terzo capitolo. Questa proposta è finalizzata a suggerire una possibile integrazione degli smart city rankings analizzati, allo scopo di accrescere l’importanza riservata alla dotazione di servizi innovativi dai loro sistemi di indicatori di smartness.

Parole chiave: smart city, ICT, IoT, UFM, big data, categorie di servizi, servizi smart, servizi innovativi, ICT-based services, smart city ranking, indicatori di smartness

Introduction

In recent years smart cities have become an increasingly discussed subjects mainly due to the technological progress of the Information and Communication Technology (ICT). In particular, the new technological solutions, which allowed to process Big Data, led to the advent of the Internet of Things (IoT). Thus, it became possible to employ ICT, especially through IoT systems, in a wide range of applications, of which the smart service provision is by far the most important for smart cities.

This dissertation is divided in two parts: the first one, which includes the first and the second chapters, is based on academic works and papers and it presents the topics introduced so far, namely the smart city concept and the ICT, and discusses the topic of the smart city rakings. The second part instead is aimed at addressing the issues raised by the first part, by suggesting proposals.

The first chapter of this study is intended to provide the reader with basic information about the definition of the concepts of smart city and of ICT. In particular it focuses on the importance and on the function of the IoT systems which, being able to process big data, have become enablers the innovative services and consequently of the development of smart cities. The architectures and the elements of which IoT systems consist, are described in detail. The approach to these topics is supported by the use of academic literature and scientific papers.
The last part of the chapter deals with Urban Facility Management services as an important field of application of IoT systems, and, more in general, of ICT. Through the use of the specific Italian and international standards, it illustrates the evolution from the FM to the UFM and describes its main features.

The second chapter starts with an overview of the Italian smart city context state of art, based on the considerations of the ANCI's Osservatorio Nazionale Smart City. Then, the chapter addresses the topic of the smart city rankings, explaining, inter alia, why they can be potentially considered tools capable of promoting the development of a city, by attracting the attention of the media, encouraging new entrepreneurs to settle in a city and boosting the real estate market.

The remaining of the chapter presents four smart city rankings which have been chosen based on their functionality with respect to the study's purposes and on the quality of the available information concerning the composition of their indicators and the sources where data are extracted. The findings of these rankings together with their systems of indicators of smartness are reported and described in detail according to the information produced by the developers of the rankings. The systems of indicators of each ranking are subsequently compared with respect to the provision of innovative ICT-based services and the best one is assessed.

The third chapter is aimed at achieving the first objective referred to in the abstract: to propose service categories aimed at facilitating the development of systems of indicators of smart city rankings focused on the provision of innovative ICT-based services.
It reports the service categorization systems for smart cities suggested by many authors and proposes a new one, specifically designed to help identify smart services and to facilitate the creation of a system of indicators of smartness focused on the provision of innovative ICT-based services. The chapter suggests also a list of innovative ICT-based services, which includes both UFM and not-UFM services. That list has been developed according to real international case studies and the main services and the sensors employed by them are described in detail and supported by examples.

The fourth chapter is meant to check the validity of the proposal of the third chapter. Thus, a qualitative mapping was performed with respect to the proposed categories and list of innovative ICT-based services. The sample of cities to be mapped has been chosen so as to be similar and comparable to that of the "best" ranking assessed in the second chapter. Not all the services of the list have been included in the mapping due to the lack of reliable data and information, however, the sources from which the data have been extracted, are reported.

The fifth chapter is intended to fulfill the second objective referred to in the abstract: to integrate the smart city rankings examined by proposing a list of indicators of smartness based on the provision of these services. To do this, it proposes a list of indicators of smartness, based on the categories and on the smart services proposed and listed in the third chapter. The chapter begins analyzing the considerations highlighted both by the mapping of the sample of cities, performed in the previous chapter, and by the indicators of the “best” ranking, examined in the second chapter, in order to pinpoint the necessity of an integration of indicators related to the provision of innovative ICT-based services. The indicators proposed are of two types, quantitative and “boolean” and the for each indicator it is reported the possible sources for data extraction. While in few cases it hasn’t been possible to directly verify the reliability of the sources, all the proposed indicators can be built employing existing data, which can be retrieved from the sources for data extraction reported. Thus, these sources indicate where to search for data and demonstrate the feasibility of the indicators, with respect to the possibility of retrieving all the data.

The final section of this study is represented by the conclusions. Besides a brief summary of the dissertation, this section discusses the strengths and the weaknesses of the work. Then, this section explaines why this study is aimed at being a useful contribution, if not a starting point, for future researches and publications in that direction. Finally, some considerations on the possible future applications of the proposals of this dissertation are presented.

PART I

1 Contextualization Of Innovative Services Enabled By ICT In The Smart City's Environment

1.1 Literary Review Of The Concept Of Smart City: Definition And Evolution

The term "smart city", according to some scholars (Rosati and Conti, 2016), was coined in the business environment of two multinationals, CISCO and IBM, in the United States of America.

Other sources (Mora et al., 2017), on the contrary, state that the term smart city firstly appeared in the published literature in 1992 in "The Technopolis Phenomenon: Smart Cities, Fast Systems, Global Networks" (Gibson et al., 1992). From then on the number of publications on smart cities grew massively: from 16 in 1992 to 9.494 in 2015.

The European Union included the term smart city inside a communitarian official document in 2009. That document was the "Strategic Energy Technology Plan" (SET-Plan) and the smart city was defined as *"a city that makes a conscious effort to innovatively employ information and communication technologies (ICT) to support a more inclusive, diverse and sustainable urban environment"* (Rosati and Conti, 2016).

The concept of smart city assumed various meaning over the years: the term smart has been interpreted in different (and sometimes almost conflicting) ways, thus many definitions have been given over the years both by scholars and institutions (Hollands, 2008).

Most of the definitions are unique and different from others because they reflect the different ways to perceive the concept of smart city and thus totally different approaches to it.

While some definitions provide a wide overall view of the aspects that characterize a smart city, others take into account only specific aspects.

Some authors focus their attention on the role of ICTs and on the technological innovations in general, while others focus their attention on "socio-economical" and "human-centric" aspects such as business-led urban development, social and human capital, e-government, social and environmental sustainability.

One of the main elements that, according to some scholars (Graham, 2002; Graham and Marvin, 2001; Komninos, 2002), is able to boost the economy of a smart city is the presence of infrastructures, such as transport and a wide range of private and public services. These authors suggested the great importance that ICTs have in making possible the existence of the aforementioned networks of infrastructures, and thus in developing the economy of a smart city and producing social and environmental benefits. According to Washburn et al (2010):

> "*what makes a [city] smart is the combined use of software systems, server infrastructure, network infrastructure, and client devices …. to better connect seven critical city infrastructure components and services: city administration, education, healthcare, public safety, real estate, transportation, and utilities*" (Washburn et al., 2010).

This view of the smart city may appear to be similar to the concept of "wired city", but it refers only to the presence of cables and connectivity without being smart. In this regard, a connection between the wired city and the social aspects of the multi-ethnic city has been proposed in Italy since the late '80s by Corrado Beguinot (Fondazione Aldo Della Rocca website)[1].

The term smart city has been used also in relation to cites that, thanks to their vibrant economy, are able to attract business and to create favourable condition for their expansion (Caragliu et al.,2009).

According to this vision, the huge capitals needed for the growth of the smart city can be injected only through private investment and public-private partnerships. For this reason, the urban development of the smart city has to be business-led.

The topic of public-private partnerships is also indirectly linked to the one of the social aspects of a smart city: the cooperation between the local government and the private entity should be deeper than the partnership. Local governments should help urban entrepreneurialism, for example by ensuring the concentration of high skilled workers, through high quality education, and by keeping reasonable tax level for businesses.

Other publications (Komninos, 2002; Hollands, 2008) argued that local governments, besides implementing policies to achieve social inclusion, should ensure that every citizen has access to ICTs in order to be an active member of the community. In other words local governments

[1] Fondazione Aldo Della Rocca http://www.fondazionedellarocca.it/corrado_beguinot.asp, Assessed on April 2018

should ensure that entire communities have online access to schools, businesses, local institutions, health and social services in order to be able to receive feedbacks and to use them to build specific services for those communities and helping the development of the smart city. This aspect is usually referred to as e-government or e-citizenship.

Some authors (Carley et al., 2001) noticed that in order to help all the stakeholders to participate and engage with a smart city, it is necessary to recognise the role of social capital (that is to say the construction of social relations and network of trust and reciprocity). In this respect, social sustainability, defined as sense of belonging and social cohesion, is a key factor in developing the smart city as an inclusive and not just as a technological city.

An example of definition of smart city that is more focused on the social aspects is provided by Thuzar (Thuzar, 2011):

> *"Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved. […] Smart cities are […] cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals."*

The element of social sustainability is often connected with the one of environmental sustainability (Hollands, 2008), which refers to all the ecological implications of the urban development of the smart city, such as the resource consumption, the generation of waste and the production of CO_2.

Another important element (Florida, 2002; Hollands, 2008; Caragliu et al, 2009) behind a smart city is the presence of cultural industries and the existence of a creative class. The concept of "creative city" is related to digital media and arts industries, and in general to all high-tech and creative industries. Those authors tried to establish a link between the development of a smart city and the existence of an environment that is safe, crime-free, tolerant, rich of cultural industries and cultural diversity.

An attempt to merge all these different aspects into one definition has been made by Caragliu, Del Bo and Nijkamp (Caragliu et al.,2009) with the following operational definition: "*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*."

The vision of the smart city behind this definition comes from *Smart Cities: Ranking of European Medium-sized Cities*, a work developed by R. Giffinger, C. Ferter, H. Kramar, R. Kalasek, N. Pichler-Milanović, and E. Meijers for the the Centre of Regional Science at the Vienna University of Technology (TU Wien) in 2007 (Giffinger et al., 2007).

According to this vision, cities are smart when they are "*well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens*". These six main characteristics, or dimensions, on which the cities are evaluated in the ranking are: smart economy, smart mobility, smart environment, smart people, smart living and smart governance.

It is interesting to notice that, according to Mora, Bolici and Deakin (Mora et al., 2017), among the works produced between 1992 and 2012, "Smart Cities: Ranking of European Medium-sized Cities" is the most influential source document as it inspired many publications concerning definitions of the smart city more oriented towards human-centric and socio-economic concepts.

The aim of this literary review on the evolution and the definition of the concept of smart city was to provide to the reader an idea of the complexity and the heterogeneity of the theme.

In the remainder sections of this first chapter the dissertation will be focused on the role of the ICTs as enablers for the rise of the smart city. In particular, it will be presented a definition of the most important of these technologies (IoT and Big Data) and it will be discussed their employment in the smart city context.

1.2 Current Scenario Of The Enabling Technologies For Innovative Smart City Services

As discussed in the previous paragraph, the definition of smart city has many facets and, thus, the growth and prosperity of the smart city rely on many different factors related both to technological and socio-human economic matters.

However, these factors are closely linked to the degree of integration of ITCs in the management of the city (Faieqa et al., 2017).

According to the Eurostat:

> "*Information and communication technology, abbreviated as ICT, covers all technical means used to handle information and aid communication. This includes both computer and network hardware, as well as their software*" (Eurostat website)[2].

Telecommunications are the key element of ICT and enable information to be consulted and widespread. Besides the more traditional means of telecommunication, such as cell phones, smartphones, wireless connections and the Internet, many new technologies spread in the last years. Form instant messaging to voice over IP (VoIP), from video-conferencing to social network websites, these new information and communication technologies allow people as well as companies to communicate in real time and also to share an increasing larger amount of information.

The reason is that ICTs are employed in smart cities in order to achieve and improve the effectiveness, the efficiency and the coordination among activities, processes, services, actors and stakeholders (Manville et al., 2014).

In other words the use of ICTs is aimed at assisting and boosting the environmental, social and economic development of the smart city. This goal is achieved by addressing challenges and solving problems concerning the "components" of the smart city and, in particular, those elaborated by the TU Wien that have been mentioned in the previous paragraph (people, economy, governance, mobility, environment and living).

Likewise, L.G. Anthopoulos (Anthopoulos, 2017) identifies eight dimensions whose cyber-physical integration constitutes the ecosystems of a smart city. Each dimension is thus integrated with ICT and all of them are integrated and interconnected together through ICT.

It is interesting to report these dimensions in order to provide a wider understanding of the application fields in which ICT can be employed in the complex smart city context.

Smart Infrastructure: It refers to the city facilities that employ ICT, such as, for example, streets, public buildings and energy, telephone, water and sewer networks. Examples of ICT employed are sensors and smart grids.

Smart Mobility (Transportation): It refers to the mobility networks that can have real time control and monitoring systems embedded.

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[2] Eurostat http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Information_and_communication_technology_(ICT), Assessed on April 2018

Smart Environment: It refers to all the ICT-based control and monitoring systems for the management and the conservation of natural resources. Examples are sensors for the control of the emission and pollution or sensors for the smart waste management and recycling.

Smart Services: It's about the employment of ICT in the provision of services such as, among others, safety, health and education. An example may be a real time remote surveillance system.

Smart Governance: It refers to the utilization of ICT in the local governance of the smart city in order to enhance participation, service delivery and engagement of citizens, for example, by digitalizing the local administration procedures.

Smart People: It refers to all the initiatives that employ ICT, such as applications, in order to improve the creativity and the innovation among the citizens.

Smart Living: It's about all the possible ways to use ICT to improve the quality of life of the urban context. For example the installation of smart sensors able to regulate climate and light and monitor performances and consumptions in buildings.

Smart Economy: It refers to all the innovative businesses and services, enabled by ICT, that are flourishing in the smart city. Examples are sharing economies services, delivery services and many others.

In the light of this, it's easy to understand the importance of ICT not only as an enabler for the development of smart systems, but also as an essential tool for the governance of the smart city thanks to its role in coordinating and managing the different subsystems.

As we can see form the dimensions indicated by L.G. Anthopoulos and listed above, there is a huge number of possibilities of application of ICT in the smart city context.

In order to provide a further idea of the complexity and of the evolution of the ICT relation with the smart city, it is worth mentioning a smart city classification elaborated by Anthopoulos and Fitsilis (Anthopoulos and Fitsilis, 2013; Anthopoulos, 2017).

The authors identified eight different classes, or approaches, of smart cities by analyzing the evolution and the employment of the ICT since the '90 in 34 representative smart cities around the world:

Web or Virtual Cities: It is the primary smart city form. It is focused on web environments providing, in particular, local information, online chatting and meeting rooms and a virtual simulation of the city such as the augment reality navigation via Web. Representative cities are the America-On-Line (AOL) cities, Kyoto, Bristol and Amsterdam.

Knowledge Bases or Knowledge Cities: These cities are defined as digital public data storages whose crowdsourcing options can be accessed via Internet and text-TV. Knowledge bases have been also defined as locally focused science, innovation and creativity within the context of an expanding knowledge. Examples are respectively Copenhagen, Craigmillar and Blacksburg for the first definition and Melbourne for the second one.

Broadband City/ Broadband Metropolis: It is related to the presence and the widespread of the connection to high speed networks by households and companies thanks to the diffusion of the fiber optic. These cities are breeding ground for private investments and in particular for telecommunication vendors. Examples are Seoul, Beijing, Helsinki, Geneva and Antwerp.

Mobile/ Wireless/ Ambient Cities: These cities installed wireless broadband networks all over their territory or only in certain district. People can access these networks with or without charges. New York, Stockholm and Florence are examples of cities belonging to this class.

The Digital or Information City: This class describes a urban context that connects physical and virtual space through ICT in order to cope with local issues. In particular, the ICT-embedded environment has to (a) contribute to local transactions and needs, (b) help the local community to transform into a local information society, (c) support the sustainable development of the local community through information collection. The examples provided are: Hull, Cape Town, Trikala, Tampere and Austin.

The Ubiquitous City: The cities belonging to this class are able to offers service and ensure data flow from anywhere to everyone. This aim is achieved through the minimization of the broadband costs and the diffusion of large scale information systems, ubitiquous computing and cloud services in the smart city context. Examples are New Sondgo, Dongtan, Osaka, Masdar and Helsinki.

The Smart City: It is similar to the Ubiquitous city, but it is more focused on the dimension of people, the citizens. Thus, this class is focused on the social aspects and, in particular, on the development human and social capital. However, it provides enterprises also with media infrastructures and broadband. Examples of cities belonging to this class are: Taipei, Tianjin, Barcelona, Brisbane, Malta, Kochi and Dubai.

The Eco City or Green City: It is similar to the Ubitiquos city, but it is focused on employing the ICT for the protection of the environment and the landscape and for the sustainable development of the city. In particular, this class promote renewable energy solutions and employs smart grids for energy production and ICT sensors for the measurement of the energy capacity of the buildings and of the environment. Examples are Amsterdam, Copenhagen, Taipei, Tianjin, Barcelona, Austin, Masdar and Dongtan.

As we can see, currently there are so many possible fields of application of the ICT that it would be impossible to address all of them in this essay.

For this reason, in this dissertation only the possible applications related to the provision of smart services will be considered.

As stated by Alcatel-Lucent (Alcatel-Lucent Market and Consumer Insight Team, 2012) with respect to the role of ICT as the key enabler of smart cities: "*machine-to-machine-to-human (M2M2H) communications technologies (also known as the Internet of Things) are basic requirements for an effective and sustainable Smart City*".

For this reason, this dissertation will focus on the innovative services enabled by ICT and particularly by the Internet of Things (IoT), regardless the class to which the smart city belongs, whether they are provided by public authorities or by private companies, be they Urban Facility Management services or sharing economy services and so on.

1.2.1 Internet Of Things And Big Data As Enablers Of Smart City Services

The Internet of Things (IoT) is regarded as one of the most, if not the most, important enabler of the future success of the smart city vision and thus, many definitions have been elaborated over the years by academic and researchers: some among the most influential ones will be reported in this paragraph.

From a semantic point of view, the meaning of Internet of Things is presented as "*a world-wide network of interconnected objects uniquely addressable, based on standard communication protocols*" by the European Commission (INFSO D.4 Networked Enterprise & RFID, INFSO G.2 Micro & Nanosystems, 2008), which also states the IoT as "*things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts*".

According to K. K. Patel and S.M. Patel, the Internet of Things refers to:

> *“the general idea of things, especially everyday objects, that are readable, recognisable, locatable, addressable through information sensing device and/or controllable via the Internet, irrespective of the communication means (whether via RFID, wireless LAN, wide area networks, or other means)*" (Patel ad Patel, 2016).

Van Kranenburg instead describes it as:

> “*a dynamic global network infrastructure with selfconfiguring capabilities based on standard and interoperable communication protocols where physical and virtual ’Things’ have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*” (Van Kranenburg, 2008).

The IoT is defined by the ITU (International Telecommunication Union) as:

> *‘‘a global infrastructure for the information society enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies”* (Ray, 2016).

As we can see from the aforementioned definitions, the key elements of the IoT are the ability to interconnect the physical and the digital worlds and the technologies able to make it possible.

In other words, IoT a system made up of sensors, physical things, actuators, IoT protocols, developers, users, cloud services and different typologies of layers. Thus, this system can be physical, virtual or hybrid.

Seven main characteristics, or key utility factors, have been attributed to IoT by S. Sebastian and P.P. Ray (Ray, 2016).

Dynamic And Self Adapting: IoT systems and devices are required to be counteracts to changing contexts, by analyzing the sensed environment, the operating conditions and the users.

Self-Configuring: IoT devices are expected to be able to configure themselves, upgrade their software and setup the networking the more autonomously as possible. In other words, they are required to perform their activity, together with other devices, with the minimal user intervention.

Interoperable Communication Protocols: IoT devices should be able to interface and share data with the components of whole system by supporting many interoperable communication protocols.

Unique Identity: IoT devices are required to have unique identities and unique identifiers in order to be queried, monitored and controlled remotely by the users.

Integrated Into Information Network: IoT devices has to be always interconnected with other devices and objects in the system. The capability of the devices to be integrated in the information network and to exchange data with the system in of major importance because it allows the system to be "smarter" by exploiting the collective intelligence that comes from the collaboration of each element of the system.

Context-Awareness: The decisions taken by the context-aware sensor nodes are based on the sensed information about the environment and the physical world.

Intelligent Decision Making Capability: IoT has a multihop nature that improve the energy efficiency of the network, incrementing its lifetime. This characteristic helps sensor nodes to cooperate in order to take collectively take the final decision.

IoT systems can be employed in several sectors and different contexts, such as for example: smart city, transportation, smart health, smart domotics, assisted living, e-governance, agriculture, retail, automation, logistic, industrial manufacturing and business/process management and many others. The importance of the employment the IoT in the management of a smart city is given by the possibility to collect a high volume of heterogeneous data, process them and, finally, use the inferred information to improve and create "smarter" services.

The rapid expansion of the IoT is exemplified by the widespread of connected devices in recent years. In 2015, it was estimated that the 5% of the objects and devices produced by human beings were equipped with embedded microprocessors, able to sense, collect and transmit different typologies of data and variables (Darwish , 2015).

The number of the connected devices in 2020 will be according to estimates 25 billion (Ray, 2016), however, Cisco estimates that the connected devices will reach in 2020 the number of 50 billion, which is roughly 7 times the current world population! (Evans, 2011)

The growing number of connected devices and thus the growing quantity of data collected and transmitted highlight and explain the importance of concept of Big Data.

Big Data are defined by Gartner as a *"high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation"* (Gartner website)[3].

In his 2001 seminal work *3-D Data Management: Controlling Data Volume, Velocity, and Variety*, Doug Laney claimed that big data ara characterized by three Vs, namely volume, velocity and variety (Laney, 2001). Since then, many researchers and academics integrated the definition with other Vs: in the following lines ae reported variability, veracity and value, in addition to the original Vs (Atta and Talamo, 2017).

The meaning of these Vs can be summarized as follows.

Volume. The rapid development and diffusion of the internet in the last two decades, led to the growth of the data volume to be managed and to the rise of new problems and solutions.

While in 2001 Doug Laney discussed the rise of the E-commerce and the consequent increase in the volume of data up to a 10x quantity for each individual transaction, in recent years we assisted to the spread of new data-generating technologies such as for example social media, social network, instant messaging and data sharing platforms that led to a drastic growth of the volume of data shared. In fact, the unit of measure of the data volume shifted from Megabyte (MB=10^6) and Gigabyte (GB=10^9) to Terabyte (TB=10^12), Petabyte (PB=10^15) and Exabyte (EB=10^18) over a period of just 20 years.

The main solution, adopted in 2001 by enterprises, to the problem of the increase of data volume was purchasing new online storage space, this exponential increase in the data volume led to new different problems related to the management of data (such as for example cost effective storage structure and excessive query time) that require the development of new solutions.

Velocity. Big Data basically consists of data streaming of packets that are quickly transmitted in a network. By increasing the point of interaction (POI) speed, the ICTs deployed by the IoT, boosted the need for a faster data interaction support and management. This means that the data streams, after being instantaneously generated, need to be quickly collected and stored.

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[3] Gartner https://www.gartner.com/it-glossary/big-data, Assessed on April 2018

Velocity is also referred to the data lifetime, which is the period of time in which data are considered useful and thus are kept stored. Big Data are also characterized by velocity because they can be consulted, aggregated and processed in real-time.

Variety. It is due to many factors such as the heterogeneity of the sources and the diversity and sometimes incompatibility of data formats and data structures.

Concerning the first factor, the sources are very different, such as for example: sensors, databases and storage systems, RFID tags, social media and many others. The heterogeneity of the sources is also one of the elements behind the diversity of formats and structures of data. The variety of the different typologies of data is huge both for digital, physical, database, storage and media documents, for example: Excel, PDF, XML, txt, paper printed documents, images, audio, video, SQL and many others.

The variety of the formats instead is expressed in three typologies: structured, semi-structured and unstructured data. Structured data follows a specific pattern such as numeric, alphanumeric and strings.

Specific patterns do not apply to semi-structured data, however they follow other rules like, for example, the tags of the HTLM language and XML files. Unstructured data instead do not follow specific rules or patterns and thus they are "open" and with a lower degree of homogeneity. Examples of this typology data are provided by videos, vocal messages and images.

Variability. Big Data are variable because their meaning varies depending on the context of the analysis and on the interpretation of each user.

Veracity. It refers to the quality, the reliability and the suitability of data and consequently to the quality of the information extracted from them.

Value. It is related to the value generated by the analysis of Big Data aimed at optimizing the decision-making process and improving the business value of the company. In particular a data driven approach, based on the latest data monitoring and analysis tools, facilitate the adoption of strategies oriented, for example, to increase the business value.

With reference to the IoT, the sensors and devices that constitute the sensing layer of the IoT, detect and transmit in real time the data stream, the Big Data. The information extracted from Big Data is particularly useful in the smart city context since it can be employed in many fields, such as Facility Management, Urban Facility Management and even in the provision of private services.

The information is inferred by analysing and processing the collected data, which are provided by the incireasing number of devices and items that are equipped with sensors and/or computational and memory functions. A typical example of these devices that had a widespread in the recent years is represented by mobile devices, such as PDAs, tablet, smart watches, smart phones and many others.
This huge amount of data is collected, transferred and aggregated through the use of the existing ICT infrastructure and particularly the wireless communication technologies (such as Wi-Fi, LTE, 3G and 4G) that became widely popular in recent years.

1.2.2 Architecture, Functional Blocks And Layered Models of The Internet Of Things

In order to provide the reader with the basic knowledge needed to fully understand the functioning of the IoT systems, this paragraph will present and describe the architecture, the functional blocks and the layered models of the IoT.
The rapid growth and diffusion of IoT led to the emergence of a vast literature about IoT architecture and models.
Several **architecture** models are currently employed in the existing IoT systems depending on the different field of application.
Firstly, it is interesting to notice that architecture and model are not the same thing: they have different meanings. The term model refers to the description of the functional aspects of the IoT, while architecture concerns the IoT logical organization view and its network topology (Ning, 2013).
A lot of research on IoT architecture has been developed: from the earlier systems based on the logic of the electronic product code (EPC) and on the concept of physical objects connected by a radio frequency identification (RFID) to the more recent SENSEI project. The latter was a project in the European Union's Seventh Framework Program that was aimed at integrating the cyber world with the real physical world, overcoming the limitations of RFID and similar technologies.
Among the various typologies of architectures that have been proposed by researches during the years, it is worth addressing to the unit and ubiquitous IoT (U2IoT) architectures.

Ubiquitous IoT is considered to be the future of IoT architecture, it should be focused on integrating physical world, cyber world and social world as well as on helping the intelligent systems that already exist to immigrate and integrate with the IoT.

The unit IoT refers to a single application, in other words to the basic unit focused on a single application and is an intelligent system that is able to control and sense things and make decisions. It is a complex architecture, organized as a man-like neural network (MLN) and it can be classified into two types.

The first one is composed by three main elements: the management and data center (M&DC), distributed control nodes and, finally, the IoT network, sensors and actuators. Those elements according to the analogy with the human nervous system correspond respectively to the brain, the spinal cord and the network of nerves. The flow of information of the system starts in the third component, and particularly in the sensors, and proceeds to the control nodes and then to the "brain". It consists of a centralized management and data center that receives, stores, translates and processes the data and then transmits the information to the actuators in order to control the things.

The second type of unit IoT is a modified version of the first one. The difference is that some distributed control nodes can work, according to the requirements, as distributed data center, which consequently are not located only in the M&DC.

Ubiquitous IoT architecture encompasses multiple IoTs applications, each of them composed by a unit IoT and a management platform, covering different services and integrating the units IoT that support these services in order to provide a higher-level service.

IoT applications include: local IoT, industrial IoT, national IoT and global application IoT.

Local IoT is composed by unit IoTs within a certain region and by the local management and data center (lM&DC) that is responsible for the management of those local unit IoTs.

Similarly industrial unit IoT consists of the unit IoTs of a specific industry and the corresponding industry management platform (iM&DC), which is managed by a specific industrial authority.

All the unit IoTs and their corresponding management platforms (both iM&DC and lM&DC) that belong to a specific nation, are managed by a national management and data center (nM&DC) and included in the national IoT.

On a global scale, the coordination of multiple national IoT, performed by a global coordinator, is referred to as global application IoT. The global coordinator could be an institution, such as the International Telecommunications Union (ITU), which is responsible for the cooperation and the coordination among Nations by means of technology, policies and standards.

The structure of unit and ubiquitous IoT is exemplified by the Figure 1.

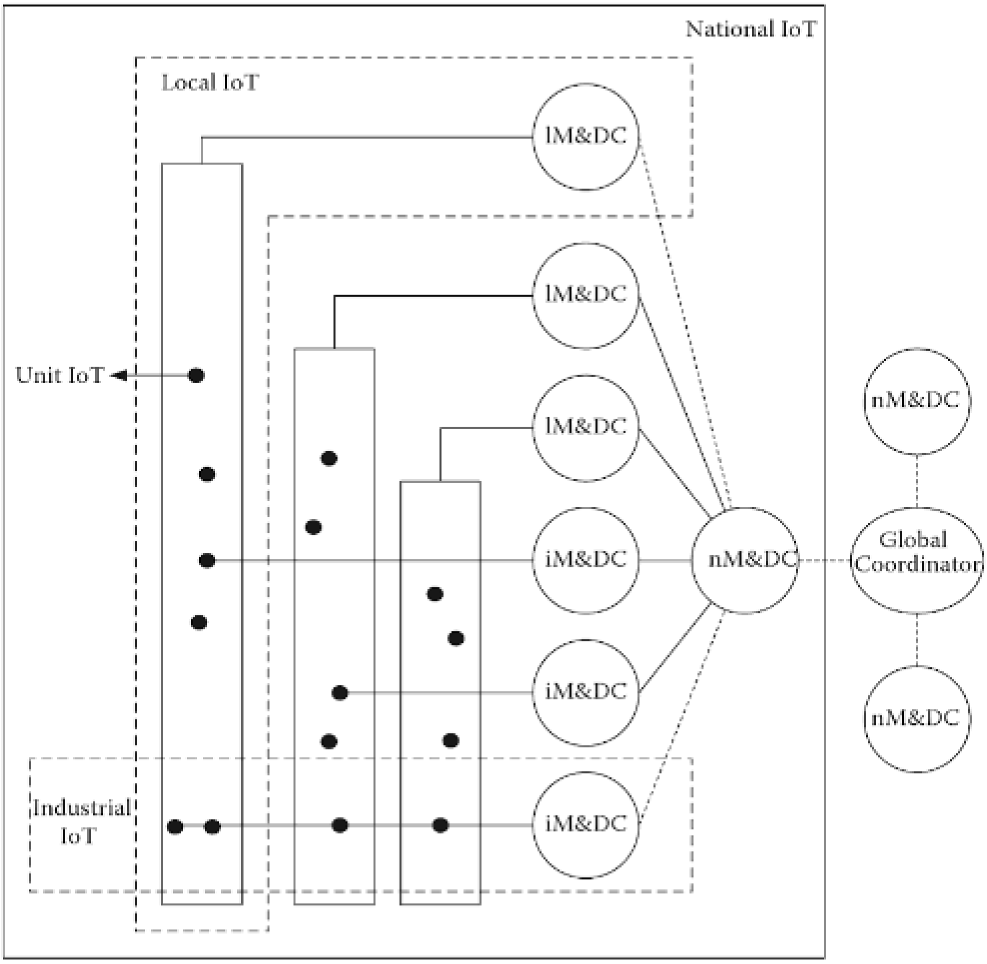


***Figure 1**: Unit and ubiquitous IoT structure. Source: Unit and Ubiquitous Internet of Things (Ning, 2013).*

The remaining part of the paragraph is be focused firstly on the functional blocks and then on the layered models.

The IoT is composed of several functional blocks that allow the system to perform its functions (Ray, 2016).

The **functional blocks** are presented and described below.

Device: Devices are the fundamental elements of which IoT systems are made up, in fact they perform four key activities: sensing, actuation, monitoring and control. Devices are only able to collect and elaborate data sensed from the environment, but they can also share data with other devices and transmit them to the centralized servers or cloud based back-end applications, enabling them to process the data or to perform tasks and activities. Devices are provided with many interfaces for communication with the both wireless and wired such as: I/O interfaces for sensors, interfaces related to Internet connectivity, interfaces for storage and memory and audio/video interfaces. Several typologies of IoT devices exist, ranging from wearable sensors and LED lights to industrial machines and automobiles. What almost all IoT devices have in common is that they produce data that in turn, after being processed and elaborated, generate information that is useful to implement further actions.

Communication: The aim of this block is to enhance communication between remote servers and devices. In an IoT system, communication protocols can be found in the application layer, transport layer, network layer and data link layer.

Services: Different typologies of functions are carried out by IoT systems: services data analytics, device control, device discovery, device modelling and data publishing.

Management: Management block performs several functions that are necessary to govern the IoT system.

Security: This block ensures the security of the IoT system through the functions of content and message integrity, authentication, data security and authorization.

Application: This block is the interface with the users, since it allows them to monitor, analyze and visualize the system status. The application layer provides the modules to monitor and control the IoT system.

As aforementioned, the term model concerns the functional aspects of IoT. In particular, models, according to the number of their layers, can have different shades of complexity, depending on which functional aspects they are focused on.

The most generic and less detailed model is the **three-layer model** that is composed by the sensing layer (also known as perception layer), the network layer ad the application layer (Sethi, Sarangi, 2017):

- **Perception layer**'s role is to pinpoint things in the physical world, to achieve and collect information from the environment and to control and interact with things. It is comprehensive of sensors, sensor gateways and actuators and it identifies other smart objects.
- **Network layer** is meant to connect to other smart objects, networks and servers and to transmit the collected data and process them. It provides secure and reliable data

transmission and, as its name suggests, consists of private networks, the Internet, mobile networks and both local and wide area networks.

- **Application layer** delivers to the users specific services, applications in which employ IoT. It is obtained by integrating IoT technologies and users' requirements: it works as an interface between the IoT service and the users. The applications of the IoT belong to a diverse set of areas. Some of the most important are subject of this dissertation and will will be described in detail in the following chapters.

More complex models can be built starting from the three-layer model and adding additional layers according to the service and to the needs of the users. An example of this is provided by the **four-layer model**, which has the same layers of the previous model with the addition of a supporting layer.

This layer is located between the two top layers (the application and the network layer) and it is intended to facilitate the exchange of data between them by using various tools, such as: data management, unified coding, data fusion and cloud computing.

A further example is reprented by the **five-layer model** which encompasses perception layer, transport layer, processing layer, application layer and business layer:

- **Perception layer:** it is the same described above.
- **Transport layer:** it is responsible for transmitting the data collected by the sensors from the the perception layer to the processing layer and the other way around. It operates through networks such as the wireless technologies that will be presented in detail later on in this chapter. This layer includes also the protocols that enable the sensing devices to communicate with the processing layer. The communication between these two layers usually employ the IP (Internet Protocols) stack. The IP stack allows the devices to communicate through the Internet without limitations in their range. It is also possible to employ communication channels which are not based on Internet Protocol, such as, for example, RFID and Bluetooth. The applications of these communication channels are characterized by lower energy consumptions and by higher range limitations with respect to IP stack. However, the architectures of protocols are usually codesigned together with the architectures of the systems and thus there are not always easily distinguishable.
- **Processing layer**, also called **middleware layer**: it is aimed at receiving, storing, analyzing and processing the data coming from the transport layer. It is able to perform different

sets of tasks and to offer many services to the other layers. It includes different technologies , like databases o cloud computing, which will be discussed in the following sections of this chapter.

- **Application layer:** it is the same described above.
- **Business layer:** it is meant to manage all the other layers and, thus, the whole IoT system in every way, including business and profit models as well as the privacy of the users.

Figure 2 shows an example of three layer model of IoT systems, while figure 3 illustrates an example of four layer model of IoT systems.

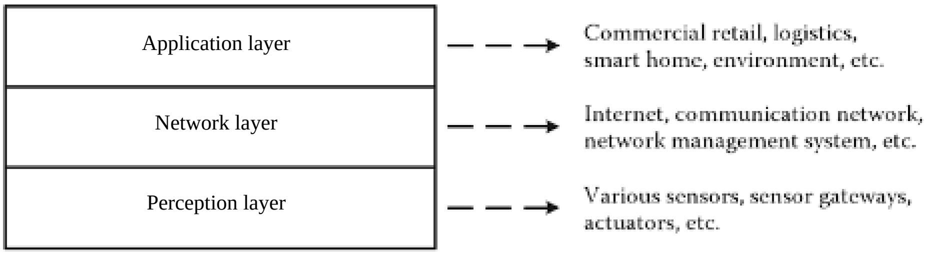


Figure 2: *Three layer model of IoT systems. Source: Unit and Ubiquitous Internet of Things (Ning, 2013).*

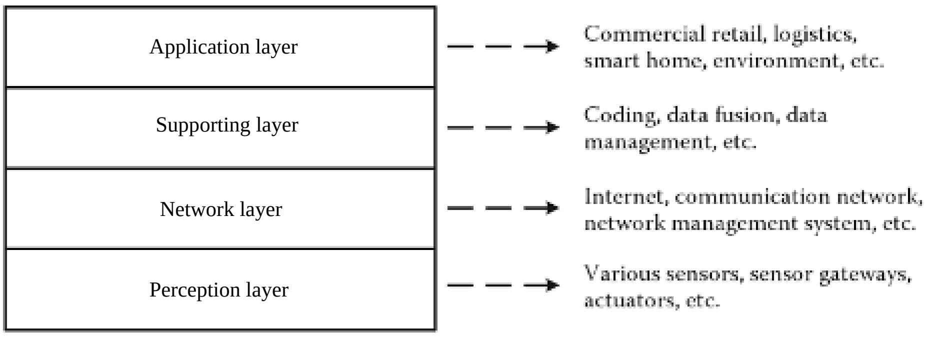


Figure 3: *Four layer model of IoT systems. Source: Unit and Ubiquitous Internet of Things (Ning, 2013).*

The activities performed by each functional block or by each layer may vary depending on the architecture of the system. For example, it is useful to report here two of the most employed architectures in the IoT: **cloud computing** and fog computing. The former one refers to those systems in which the computing activity is centralized and performed by cloud computers, that is to say by a network of servers and computers connected together via Internet. It is characterized by scalability and flexibility and it enable to quickly access large quantity of data.

Fog computing is similar to the concept of edge computing, sometimes the two terms are used as synonyms. It refers to an architecture in which some processes are managed directly by the smart sensing devices at the edge of the network, while other processes are centralized and managed by the cloud network. Fog computing performs the activities of monitoring, storage, security and, preprocessing. The latter activity is particularly important since it reduces tha amount of data that need to be transported to the cloud, by analysing and filtering them.

1.2.3 Perception Layer, Transport Layer And Processing Layer: Solutions And Technologies

Sensors, Actuators And Transductors

In an IoT system, information is sensed and collected by the first element of the device functional block, the sensor. Sensors transform a non-electrical imput in an electrical signal that is compatible with an electronic circuit. However, usually the term sensor is used to identify not only sensors but the whole sensing system, which encompasses also micro-controllers, modem chips, power surces and other devices. According to the Institute of Electrical and Electronics Engineers (IEEE) a sensors is:

> ”*an electronic device that produces electrical, optical, or digital data derived from a physical condition or event. Data produced from sensors is then electronically transformed, by another device, into information (output) that is useful in decision making done by “intelligent” devices or individuals (people)*”(Holdowsky et al, 2015).

By coupling together different sensors, each with its own purpose, it is possible to obtain complex systems that are able to collect and process several kinds of information.

The other key element of the device functional block is represented by the actuator, which is able to convert an electric signal into some form of useful energy in order to change the environment. Depending on their functioning, actuators can be divided into three categories, namely, electrical, hydraulic and pneumatic(Sethi, Sarangi, 2017). Electrical ones use electrical energy while pneumatic ones employ the pressure of compressed air. Finally, hydraulic actuators use fluid or hydraulic power to achieve mechanical motion.

Some common example of actuators are speakers, heating and cooling systems, as well as the devices employed by home smart systems to switch on/off the electrical appliances, to lock/unlock doors, to alert owner of any kind of internal and eternal threats and so on.

Both sensors and actuators belong to the category of the transducers. A transducer is a device that is able to transform one form of energy into another form of energy, not necessary electrical energy (Holdowsky et al, 2015).

The success and the widespread adoption of sensors in the IoT-based applications are due to mainly to three factors:

- **price**. Sensors prices vary according to their typology, however they have became cheaper in the last 25 years since their price falls from an average of 22$ in 1992 to an average of 1,40$ in 2014;
- **capability**. The technological development of the last two decades enabled a substantial improvement in the performances of power sources and microprocessors, with the computational power that doubles every three years, and this led to an increase in the smartness of the sensors;
- **size**. The widespread of smartphones and wearables has led to the development of smaller and economic sensors. Besides smartphones, the size of the sensors is very important for many application such as those related to the health care industry and those concerning Micro-electro-mechanicnal systems (MEMS) and nanotechnologies in general.

These three factors are of crucial importance, in fact, the cheaper, smarter and smaller is a sensor, the wider is the range of applications it can support and the larger is the amount of data it can generate and manage.

The most important among the main characteristics of a sensor, which are those according to whose performances a sensor is considered suitable for a certain application, are accuracy, repeatability, range, noise, resolution and selectivity.

Accuracy refers to the precision of a sensor in reporting the value of the signal sensed. **Repeatability** reflects the ability of a sensor in reporting the same feedback on equal inputs and environmental conditions.

The **range** of a sensor is the interval between the maximum and the minimum values of a parameter that ca be measured without compromising the accuracy and the operability of the sensor.

Noise is referred to the variations in the output signal due to the environmental conditions or to the sensor.

Resolution is the smallest incremental change that a sensor is able to detect in the input that it is measuring.
Selectivity reflects the ability of a sensor to selectively sense nd report a certain signal among other signals.

A first way to categorize sensors is according to their power sources, they can be active or passive.
An **active sensor** emanates energy and receives the respons of the environment to that energy. On the contrary, a **passive sensor** simply collects a specif type of energy (according to its purposes) from the environment.
A well-known example of active sensor is the Radio Detection and Ranging (RADAR) that produces energy in the form of radio waves, while a videocamera is an example of passive sensor which receives energy in the form of light.
Another way of classifying sensors is according to the functions that they perform in the applications in which they are commonly employed. A huge number of sensors, both active and passive, is currently used in IoT applications, however the majority of them, as well as the most commonly employed, can be grouped into thirteen types:

position. They are meant to detect and measure the position of an object in absolute terms or in relative terms, depending on whether they are absolute position sensors or displacement sensors. They can be angular, linear or multi-axis. Common examples are proximity sensor, potentiometer and inclinometer;

occupancy and motion. The former identify the presence of people and animals in a certain surveillance area, while the latter detect movement of objects and people. Motion sensors, differently from occupancy ones, do not generate a signal when an object or a person is stationary. Common examples are RADAR and electric eye;

velocity and acceleration. The former measure the speed of an object which moves along a straight line or spins, while the latter measure changes in velocity. Examples are the gyroscope and the accelerometer;

force. They recognize whether a physical force is applied and measure its intensity in order to compare it with pre-determined thresholds. Common examples are tactile and touch sensor, viscometer and force gauge;

pressure. They are similar to force sensors and the they measure the force applied by gasses or liquids. Examples are piezometer, barometer and bourdon gauge;

flow. They refer to the measurement of fluid flows both in terms of volume and rate. In fact, they are able to measure respectively the mass and the velocity of a flow that runs through a system in certain period of time. Common examples are water meter, anemometer and mass flow sensor;

acoustic. They are aimed at catching and measuring sound signals and transform the information into outputs in the form of digital or analog signals. Examples are geophone, microphone and hydrophone;

humidity. These sensors are able to detect and measure the amount of water vapor in the air or in a mass. The level of humidity can be assessed in different ways, such as by looking at the relative humidity, the absolute humidity and so on. Examples are provided by the humistor, the hygrometer and the soil moisture sensor;

light. They are able to perceive the presence of both visible or invisible light. Flame detector, infrared sensor and photodetector are some examples;

radiation. They are meant to sense radiations in the environment by using two operating principles, namely scintillating and ionization detection. Common examples are neutron detector, Geiger–Müller counter and scintillator;

temperature. They assess the amount of heat or cold of a system and they can be grouped into two types, namely contact and non-contact. The latter are able to measure temperature through convection and radiation and thus they do not require physical contact. On the contrary contact sensors need a physical contact in orer to sense the temperature of an object. Calorimeter, temperature gauge and thermometer are typical examples;

chemical. They assess the presence of chemical substances and measure their concentration. They are also able to detect the chemical substance they are required to measure among other substances. Common examples are olfactometer, breathalyzer and smoke detector;

biosensors. They are able to assess different kinds of biological elements such as tssues, enzymes, organisms, cels, nucleic acids and antibodies. Pulse oximetry, blood glucose biosensor and electrocardiograph are examples of biosensors.

Chapter 3 reports the most important typologies of sensors currently employed in the development of the IoT-based services provided in the smart cities.

Communication Technologies

As aforementioned in the previous section, the transport layer is of paramount importance for IoT systems, since it allows the transmission of data from the the perception layer to the processing layer and the other way around.

Different typologies of wireless communication technologies are currently employed in transport layers (Ray, 2016):

802.11, commonly known as **WiFi**: The IEEE 802.11 is a set of standards developed by the Institute of Electrical and Electronics Engineers (IEEE) that contain the specifications for implementing a Wireless Local Are Network (WLAN). The standards, which are commonly known as WiFi operate in different bands ranging from 2.4 GHz to 60 GHz, 2.4 GHz, 5 GHz and 60 GHz. The data rate of IEEE 802.11 standards ranges from 1 Mb/s to 6.75 Gb/s while their communication range goes from 20 m, for indoor use, to 100 m for outdoor use. This technology is characterized by high energy consumption and cost.

802.16, also known as **WiMax**: The IEEE 802.16 is a family of standards related to the Worldwide Interoperability for Microwave Access (WiMax) technology. Its frequency band goes from 2 to 66 GHz while its data rate ranges from 1 Mb/s to 1Gb/s for fixed stations and from 50 Mb/s to 100 Mb/s for mobile stations. Its transmission range is inferior to 50 Km and it is defined by a high cost and a medium energy consumption.

802.15.4, LR-WPAN: IEEE 802.15.4 is a standard that describes the functioning of the Low-Rate Wireless Personal Area Network (LR-WPAN) technology. This standard contains the specifications for the for high level communication protocols such as Zigbee. The latter is a low-power ad hoc network that is usually employed in fields characterized by low-bandwidth need, such as home automation and medical devices. In fact, the data rate of LR-WPAN is quite low, ranging from 40 kb/s to 250 kb/s. It operates at 2.4 GHz and from 868 MHz to 915 MH frequencies. It is characterized by low cost and low energy consumption.

2G/3G/4G, Mobile Communication: Mobile communication encompasses four generations and allows devices to communicate through cellular networks, thus this technology has no transmission range limitations. The first generation (1G) was based on the first telecommunications standard and it differs from the second generation because it employs analog radio signals, instead of digital ones. However 1G technology is almost disappeared all over the world.

The second generation (2G) was initially based on the GSM (Global System for Mobile communications) standard and then on GPRS (General Packet Radio Service) standard and on CDMA (Code-Division Multiple Access) standard. Enanchement of the second generation are 2.5G and 2.75G. The third one (3G) comprises the UMTS (Universal Mobile Telecommunications Service) standard, the CDMA2000 standard and the EDGE (Enhanced Data rates for GSM Evolution) standard. The fourth generation (4G) is mainly based on the LTE (Long-Term Evolution) standard, from which it is sometimes named. The 4G+ (or plus) is based on the LTE Advanced standard, from which it is alternatively named, and it is basically an enhancement of the LTE. The fifth generation (5G) is the first cellular mobile communications generation conceived to fully support the applications of the Internet of Things. It is based on the eMBB (enhanced Mobile BroadBand) standard, the mMTC (massive Machine Type Communications) standard and the URLLC (Ultra Reliable Low Latency Communication) standard. However, it is still under development and its deployment will start between 2019 and 2020.

The brandwidth of 1G was 2.4 Kbps, while that of the second generation ranges from 14.4 kbps to 64 kbps. The brandwidth of the third generation is 2 Mbps, while that of the 4G ranges from 200 Mbps to 1 Gbps. The brandwidth of the 5G is expected to be more than ten times the value of the previous generation (Kalra and Chauhan, 2014). Mobile communication is a medium energy consumption and medium cost technology.

802.15.1, commonly known as **Bluetooth**: IEE 802.15.1 standard defines Bluetooth, a technology characterized by low cost and medium/low energy consumption (the ultra low cost and low power version is the Bluetooth Low Energy also known as BLE and Bluetooth Smart) that enable mobile devices to share data in a range from 8 m to 10 m. It has a band frequency of 2.4 GHz while its data rate goes from 1 Mb/s to 24 Mb/s.

LoRaWAN R1.0: LoRaWAN is a communication protocol, developed by LoRa Alliance, a non-profit organization aimed at ensuring the interoperability and the standardization of Low Power Wide Area Networks (LPWAN) in order to facilitate the implementation of the IoT. LoRaWAN operates in a range 30 Km in an open environment, on band frequencies between 868 and 900 MHz and its data rate goes from 0.3 Kb/s to 50 Kb/s. While it is a very low-cost technology (it employs batteries whose life is up to 10 years), it is quite expensive.

Pre-processing And Middleware

As aforementioned the **preceprocessing** phase is required when an IoT system employs a fog architecture. In fact, when problems like arise, it is necessary to adopt a fog computing and preprocessing solutions, in order to solve them.

The factors that led to the adption of **fog computing**, instead of the more traditional cloud computing are:

- *mobility*. It is related to the mobile devices, whose continous changes of locations often result in problems and difficulties in the communication with the centralized cloud network;
- *reliability and latency*. It refers to the applications that requires real time data and responses from the cloud. These application cannot tolerate the latency caused by the communication time. In addition, certain applications need highly reliable data, and not the lossy data that may result from the wireless communication;
- *scalability*. The greater the number of smart devices communicating with the cloud network, the greater the latency;
- *power constraints*. Since smart devices are powered by batteries, they may need to save power by avoiding to communicate continuously with the cloud.

Thus, the adoption of a fog computing architecture decreases latency by reducing the time needed for computing and eliminates the problems related to the change of location and to the loss of quality of data during communication. In addition, fog computing can also employ several nodes distributed in different geographical areas which, as opposed to the centralized cloud, are able to further ensure real time responses and support the mobility.

Preprocessing is perhaps the key activity of fog computing because by filtering and preprocessing the collected data smart devices are able, for example, to reduce communications with the cloud, to transmit to the cloud only the necessary data and to monitor and reduce the power consumption.

It important to remind that the fog computing architecture is always implemented together with the cloud computing and it not alternative to it because it performs only those activities that cannot be processed by the cloud.

Middleware can be defined as a software layer, located between the operating system and the applications, that is able to abstract the hardware and to support the applications. Middleware, in fact, enable and factilatate the computing activities and the interactions between computers, servers and databases of the cloud. It provides an Application Programming Interface (API) supporting data management, computation, security and communication, thus helping the developers of applications to be able to concentrate on the applications rather than on their interaction with the cloud.

Middleware simplifies the interaction and data exchang between heterogenous devices, ensuring the interoperability on three levels: network, syntactic and semantic. The latter refers to the ability to tranmsit data with a shared meaning. Syntactic interoperability enables the different applications to exchange data, regardless the differences in encoding, formats and structures of data. Network interoperability, instead, allows devices, which have different interface protocols, to communicate with each other.

Middleware is able to made each device announce its presence, as well as the services that it offers, to the other devices of the IoT infrastructure. It is also aimed at managing this huge number of devices ensuring the scalability.

Middleware has also an important role in the the management of the collected big data in terms of ensuring their processing, security and privacy. Sophisticate big data algorithms performs activities like analysis, processing and context extraction and, when the data are incomplete, they are able to extrapolate useful data.

The different typologies of middleware are classified according to their design: event based, service oriented, database oriented, semantic and application specific.

1.3 Urban Facility Management (UFM) As A Field Of IoT Application In Smart Cities

1.3.1 From Facility Management To Urban Facility Management: Evolution Of The Concept

As aforementioned, an important field of application of ICT in the smart city context is Facility Management, and, to be more precise, Urban Facility Management, as it will be showed in this section.

Thus, the aim of this paragraph is to provide the reader with the key concepts of the FM and the UFM that are needed to understand the development of this dissertation.

The European Standard EN 15221-1 (CEN, 2006) defines the Facility Management as the "*integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities*".

Facility Management in Italy nowadays is increasingly linked to urban context and to needs of the city (Curcio, 2006).

The city can be seen a macro-system that encompasses three sub-systems or levels: the underground level, the ground level and the above ground level.

The **underground level** consists of:

- *Techno-networks such as gas, electricity, water etc*
- *Info-networks such as info-wiring*

The **ground level** is made up of:

- *Streets and squares*
- *Urban furniture*
- *Green areas and parks*
- *Lightining and traffic lights*

The **above ground level** is composed by:

- *Single buildings*
- *Real estate*
- *Historical monuments*
- *Infrastructure such as airports, railway stations etc*

Thus, Facility Management in Italy evolved in recent years towards a new concept of management of urban facilities, this new trend is called Urban Facility Management.

Urban Facility Management (FMU), according to Italian standard UNI 11447 (UNI, 2012), can be seen as the integrated management of the support services needed for the proper functioning, use and valorization of urban properties and facilities. FMU may involve the tendering of just one service or the tendering of multiple services, depending on the specific needs and on the management strategies of urban property that have been adopted.

As with the Facility Management (CEN, 2006), the definition of the difference and the relationship between primary activities and support activities/services is the competence of the contracting entity. Support activities and the tangible assets (facilities) represent the inputs of the facility management process, while the results of these activities, which coordinate and integrated the primary activities, are the output of the process.

Both Facility Management and Urban Facility Management are developed along three main levels which are intended to improve the coordination between all the actors involved and the objective of the contracting organization, thus helping to achieve the expected results.
The **strategic level**, the first one, aims at meeting the long-term objectives set out in the organization's strategy and it is comprehensive of different activities such as: defining FM strategy and supervise FM process, defining policies and guidelines, providing input and responses to the lower level, keeping relations with all actors involved and authorities, managing externalities and impacts of the services, starting risk analysis, service level agreements (SLAs) and key performance indicators (KPIs).
The **tactic level** consists of the implementation of the strategic objectives in the medium term through different activities such as: implementing and monitoring guidelines and policies defined by the higher level, converting long-term strategic objectives into short-term operational activities, creating business plans and budgets, determining SLAs and interpreting KPIs, checking with laws and regulations, optimizing the use of resources, managing the communication with external or internal service providers on a tactical level, adapting to and informing about changes, managing agreements, processes, projects and the FM team.
The third level, the **operational** one, refers to a day-to-day basis and it aims at developing the proper environment to the end user through: providing services meeting the SLA and checking their delivery process, controlling the service providers, managing the requests for service via service line or help desk, managing the communication with external or internal service providers on an operational level, reporting to the higher level, gathering feedback and demands from end users and data in order to evaluate performances.
Concerning Urban Facility Management, a fourth level is added in the standard UNI 11447: it is the **users level** and it represents the end users that will experience the results of the UFM services.

1.3.2 Key Elements Of The Urban Facility Management: Urban Property, Service Typology And Actors Involved

In this section the key elements of the Urban Facility Management will be presented and described according to the aforementioned UNI standard. Firstly, a complete classification of urban property and then an actual classification of Urban Facility Management services will be provided. Finally, the classification of the FMU interested parties will be produced.

In order to identify the FMU services and possible interferences between them, a proper classification of the typologies of urban property is needed. This classification is also an indispensable element for many other reasons, since it helps to show the links between each property and the related service/services, to manage the service quality control system, to create a registry systems for urban property and to develop the planning of services.

The **classification of urban property** is based upon the definition of seven typologies of urban functional areas: technological infrastructures, road networks, waterways, public green areas, street furniture, transport infrastructures and other urban functional areas. Each of them has an associated set of urban properties.

Table 1 shows the classification of urban properties based on their functional areas.

URBAN FUNCTIONAL AREAS	URBAN PROPERTY
Technological Infrastructures	Public lighting and traffic lights
	Electricity networks
	Gas networks
	Water networks
	Heating/Cooling networks
	Telecommunications networks
Road Networks	Streets and adjacent areas
	Sidewalks, pedestrians areas and other public spaces
	Parking lots
Waterways	Rivers, canals and navigable channels
Public Green Areas	Villas, parks, gardens and forests
Street Furniture	Fixed and mobile furniture
Transport Infrastructures	Infrastructures for public transport
Other Urban Functional Areas	Other urban property

Table 1: *Urban properties classification based on their functional areas. Source: UNI 11447 (UNI, 2012).*

Each urban property can be interested by a single FMU service or by multiple services, and each FMU service can be applied to a single or to multiple urban properties.

Each **FMU service** should be defined and described according to a **classification** system that is expected to provide clear and uniform definitions of each service, to allow benchmarking, to promote a more integrated management of services, to make the performance levels measurable and comparable, to properly produce data and allocate costs. In addition, the service classification, together with the urban property classification, is useful to recognize all possible interferences between different services and to optimize the provision of services, highlighting all possible synergies and redundant activities.

FMU services fall into four different categories: services to the territory, services to buildings, plants and infrastructure, services to the environment and individuals, services for the administration.

Table 2 shows in detail a list of the main FMU services associated to each category.

CATEGORIES	FMU SERVICES
Services To The Territory	Maintenance, monitoring and verification of urban furniture
	Maintenance, care and monitoring of public green areas
	Maintenance and care of land and plants/installations
	Maintenance and monitoring of road surface markings, vertical road signs and luminous road signs
	Technical engineering support necessary for the development of land-use planning
	Verification, monitoring and control of the road network
	Maintenance of road surface and quick response for dips
	Urban decorum
	Snow clearance, salt scattering and de-icing
	Parking management
	Other services
Services To Buildings, Plants And Infrastructure	Maintenance of buildings and their systems
	Management, operation and maintenance of heat station and heating systems
	Management, operation and maintenance of air treatment systems
	Management, operation and maintenance of water and sewage systems
	Management, operation and maintenance of electrical and lightening technologies systems
	Management, operation and maintenance of the technological security systems
	Management, operation and maintenance of technological control systems
	Management, operation and maintenance of elevators and lifting systems

	Management, operation and maintenance of phone and data transmission networks
	Management of special systems
	Availability and quick response
	Other services
Services To The Environment And Individuals	Environmental cleanliness and hygiene
	Extermination, disinfection and deratting
	Waste collection and disposal
	Reception and security
	Call centres
	Management of documents, archives, print and similar
	Space management
	Other services
Services For The Administration	Provision and management of registries and inventories
	Provision and management of information systems
	Management of command centres
	Other services

Table 2: *List of the main FMU services. Source: UNI 11447 (UNI, 2012).*

Actors involved in FMU services are classified into four classes, according to the different context and to the role played by each of them. Each class has a correspondent level of interaction: strategic, tactic, operative and users' level.

The first class is represented by clients. They are territorial entities who have to set out the needs and the strategic requirement and thus they operate on the strategic level.

The second class, which correspond to the customer and to the tactic level, is composed by territorial entities or special-purpose entities that have to acquire the services and to manage the relationship with the providers of the services. The latter are the third category: they are required to provide the services and thus they are the operative represent the operative level.

Finally, the fourth category correspond to end users of the services, such as individuals, entities and economic entities and thus it the users' level.

2 Smart City Rankings And Indicators Of Smartness

2.1 Overview On The Current Situation Of The Smart City Context In Italy

After having provided some basic concepts related to the smart city and ICT in the first chapter, the next step of this dissertation is to inform the reader of the current situation of the Italian smart cities. The next paragraph is dedicated to the decription of the tool employed to perform this activity: the city rankings, and, in particular, those that rank cities according to their smartness. Four smart city rankings are reported and the presence of Italian cities is pinpointed.

The third paragraph of this chapter presents a complete list of all the indicators and factors that have been employed by the creators of the rankings in order to assess the smartness of each city.

In the fourth paragraph the rankings are compared with respect to the importance of the indicators related to the smart service provision in each one, and, as a result, the best one is assessed and chosen.

The Italian urban context is made up of by a large number of Municipalities with less than 10.000 inhabitants and very few big cities. As in 2013, the 85% of the Italian Municipalities were small populated areas with less than 10.000 inhabitants and there were only 15 cities with more than 200.000 inhabitants (Osservatorio Nazionale Smart City, 2013).

The current situation of the Italian urban context can be summarized in three different typologies.

Firstly, there are 5 big cities (Genoa, Turin, Bari, Milan and Florence) that have undertaken the process of transformation into a smart city by adopting integrated approaches which aims at managing the dimensions and the actors of the city as a whole.

Secondly, there is a huge number of medium-sized Municipalities that are have already planned to follow integrated management approaches through the adoption of policies concerning different fields such as e-government, valorization of cultural heritage, sustainable mobility and many others.

Finally there is still a number of urban contexts, significant both in terms of territorial extension and infrastructural dimension, that are lagging behind in the implementation and in the adoption of integrated management models and approaches.

The concept of smart city in Italy, despite the absence of megalopolis, is gradually growing in importance and it has become a priority in many local governments.

The substantial increase in the importance of the smart city concept is reflected by the birth of the Osservatorio Nazionale Smart City (Smart City National Observatory), which was created in April 2012 by ANCI (Associazione Nazionale Comuni Italiani) and it is managed by a partnership between ANCI and FORUM PA, a private entity involved in many other projects and partnerships with public entities.

The aim of the Osservatorio Nazionale Smart City is to replicate in Italy the European smart city development model, by adapting it to the context of the Italian cities.

According to the "Vademecum per la città intelligente", a document produced by the Osservatorio Nazionale Smart City that shows the state of the art of Italian smart cities in 2013, the years 2011-2012 represented a turning point since many municipalities (Comuni) started to include in their agenda policies related to the smart city.

This rise of smart city projects appears to be strongly linked to the concomitant existence, in the Italian context, of at least three main factors:

- the initiatives taken by the European Union. In particular, the European Industrial Initiatives (EII), as part of the implementation of the SET-Plan, and the initiatives for digital innovation of internet services in the smart cities, as part of the Competitiveness and Innovation Framework Programme (CIP), and other programmes;
- a shrinkage in the available resources of public entities. In fact, this reduction makes it necessary, in order to seek efficiency, to improve the allocation of resources, through the deployment of new technologies;
- the active participation of the Central Government, exemplified by the institution of the Agenda Digitale Italiana (ADI), through the Law Decree 179/2012, and by the calls for researchers opened by the MIUR (Ministry of Education, Universities and Research), which allocated roughly EUR 1 billion.

The above mentioned factors are made effective by the willingness of the local administrations to find new ways and tools able to ensure the development of their city and its transition into a smart city.

The Italian local Administrations developed two different approaches towards smart cities: the **vertical** one and the **systemic** one. The first one is the most common and it deals with one or several issues related to the city context, such as for example mobility and transportation system. The systemic approach, on the other hand, considers the smart city as a socio-technical systems composed by several dimensions and able to support and foster the innovation process.

In particular, the dimensions that are addressed by the local Authorities are the **economic** one, the **social** one and the **governance** dimension. The first one is about policies concerning sustainable development, research and development and the attentions towards innovative activities and human and financial capital. The second one deals with social issues such as the importance of social and relationship networks, tolerance, social inclusion and the defense of the public good. The governance dimension involves the smart-governance polices aimed at enhancing the consensus and the participation of all the actors involved in the city context (such as citizens and companies) in the local decision-making process.

The aforementioned approaches and the actions of the Administrations are aimed at improving the life of the community by enabling the integration between the technological infrastructure, the people and the socio-economical aspects.

2.2 Review Of International Smart Cities By Analysing Different Smart City Rankings

As already explained in the first chapter of this dissertation, there are different interpretations of the smart city concept and of its characterizing fields. Thus, many rankings exists or have been produced by several institutions, according to the smart city concept adopted and to the fields considered.

In the last two decades city-rankings have gained more and more importance: they have turned into crucial tools for the evaluation of the attractiveness of cities and they are now recognized by the local administrations as key elements in the marketing strategies for the promotion of the international image of the cities.

However, it is important to notice that there isn’t a direct connection between the rating of a city in a city-ranking and its actual economic performance. In fact, as observed by R. Giffinger and H. Gudrun (Giffinger and Gudrun, 2010), city-rankings are built considering different data and indicators and assigning specific weights according to the purpose for which they are developed. In other words the result of a ranking depends on the methodologies employed and on the target that the developers want to achieve.

The target audience is also a very important element that has to be taken into account during the development of the ranking. Usually the audience of rankings is represented by companies with expatriates, by the expatriate themselves and by local politicians and administrators of cities and communities. Thus the information that can be typically found in a city-ranking may be summarized in two typologies: the information concerning certain costs of living or individual development chances and the information concerning list of advantages/disadvantages, level of development, characteristics of a city with respect to its competitors.

City-rankings present both positive and negative aspects as well as side effects that have to be taken into account before starting to analyze each ranking.

The release of a city-ranking is able, at the same time, to draw the attention of the mass-media towards a region science issues and to encourage politicians and local authorities to promote and discuss new strategies to solve these issues.

Besides being elements of self-promotion marketing for cities, city-rankings can also help local actors and local administrators of a city to find and implement a development-strategy in order to be competitive with respect to the other cities.

In addition, by internationally promoting the image of a city, rankings may force the local actors involved in decision-making process to make transparent and comprehensible decisions.

On the other hand, rankings are usually unlikely to take into account the complex interrelations and causalities that exist in the city context because they are only focused on the ranking results. Plus, the fact that the public attention is given only to the final ranking implies that the methodologies behind the ranking are often neglected or considered as a footnote.

Another undesirable effect is that city-rankings may boost existing stereotypes and clichés especially in case of a wrong public perception of the ranking and of a non-transparent city sample selection.

Furthermore, since city-rankings enhance competition among cities, they may negatively affect long-term development strategies by bringing negative consequences and problems.

Moreover city-ranking tend to be misinterpreted by public and the administrators: in fact the results of the ranking are usually excessively praised by the cities on the top and totally ignored by the cities on the bottom.

Finally, many city-rankings are required by financers to produce results that can be easily presented to the public and thus they may have an excessively superficial approach, ignoring many elements and the actual context and dynamics.

In the following paragraphs four rankings, each one with a specific list of indicators of smartness, will be presented and described.

They have been chosen out of all the smart city rankings currently available based on their accessibility and visibility, in terms of citations in academc papers, and on their functionality with respect to the study's purposes. In particular, the latter point means that many smart city rankings have been assessed in order to evaluate the quality of the information, provided by the their developers in the final reports, as regards to the methodologies and the sources for data extraction. Many ranking developers do not include a detailed description of the methodologies that have been followed to buit the indicators or a comprehensive list of the sources from which data have been extracted. They do it on purpose and for various reasons, one of which may be to maintain the competitive advantage for as long as possible, avoiding to show to their competitors their methodologies and sources.

Thus, the rankings that failed to include in their final report the information concerning how the indicators were obtained and the sources for data extraction employed, were not taken into account in this study.

The rankings analyzed in this section are:

- The **Ranking Of European Medium-Sized Smart Cities** by the Vienna University of Technology (TU Wien) (Giffinger et al., 2007);
- The **IESE City In Motion Index (CIMI)** by the IESE Business School of the University of Navarra (IESE, 2018);
- The **2017 Smart City Index** by EasyPark (EasyPark Group website)[4];
- The **ICity rate 2017** by FORUM PA (FORUM PA, 2017).

[4] EasyPark Group https://easyparkgroup.com/smart-cities-index/, Assessed on April 2018

Ranking Of European Medium-Sized Smart Cities By The TU Wien

The *Ranking Of European Medium-Sized Smart Cities* is a project developed in 2007 by R. Giffinger, C. Ferter, H. Kramar, R. Kalasek, N. Pichler-Milanović, and E. Meijers for the the Centre of Regional Science at the Vienna University of Technology (TU Wien) in 2007. It consists of the ranking of 70 European medium sized smart cities, with a population between 100.000 and 500.000 inhabitants.

According to the developers of the ranking, most of the European population today lives in cities of medium size, but these cities are seldom considered in the academic literature since the focus of researches is on the large size metropolis that are recognized on a global level.

This observation was the reason behind the choice of ranking smart cities of medium size. Thus, the ranking was aimed at identifying the strengths of each city and at helping them to create comparative advantages over other cities by focusing on certain resources and developing certain fields.

The project has been published in 2007, however the ranking of medium sized cities was updated in 2013 and 2014 while in 2015 a ranking of large cities, with a population between 300.000 and 1.000.000 inhabitants, was started but it has not yet been completed. Here it will be discussed the first version of the ranking (2007) because more data are provided with respect to the following versions.

Due to the lack of a universally accepted definition of medium-sized city, the authors decided to considers those cities that are very important on a regional scale but that are not recognized at European level.

The starting point of the methodology employed to choose the sample of cities was to analyze the Epson 1.1.1 study which provides 1.600 cities or functional urban areas (FUA). The next step of the selection process was to apply to three criteria to the cities provided by the Epson study: the cities were selected among those with a population between 100.000 and 500.000 inhabitants (medium-sized), with at least one University (to ensure rich knowledge basis) and with a catchment area that is less than 1.500.000 inhabitants (to eliminate cities dominated by bigger cities). The number of cities that met these criteria was 256 and it was further decreased to 94 by considering only the cities covered by Urban Audit, which is a large European database on cities.

The second and final step for the selection process of the sample of cities consisted of the elaboration and adjustment of the previously found sample with a focus on the quality and the accessibility of data. The final sample obtained through this methodology encompasses 70 cities.

The cities of the aforementioned sample have been evaluated according to the performances achieved in six main characteristics (smart economy, smart mobility, smart environment, smart people, smart living and smart governance) and indicators, as it will be described in detail in the next paragraph.

Table 3 shows the performances of each city both in the six main characteristics and in the final ranking and highlights the Italian cities.

Country	City	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living	Total Rank
LU	LUXEMBOURG	1	2	13	6	25	6	**1**
DK	AARHUS	4	1	6	9	20	12	**2**
FI	TURKU	16	8	2	21	11	9	**3**
DK	AALBORG	17	4	4	11	26	11	**4**
DK	ODENSE	15	3	5	5	50	17	**5**
FI	TAMPERE	29	7	1	27	12	8	**6**
FI	OULU	25	6	3	28	14	19	**7**
NL	EINDHOVEN	6	13	18	2	39	18	**8**
AT	LINZ	5	25	11	14	28	7	**9**
AT	SALZBURG	27	30	8	15	29	1	**10**
FR	MONTPELLIER	30	23	33	24	1	16	**11**
AT	INNSBRUCK	28	35	9	8	40	3	**12**
AT	GRAZ	18	32	12	17	31	5	**13**
NL	NIJMEGEN	24	14	14	3	51	24	**14**
NL	GRONINGEN	14	9	15	20	37	13	**15**
BE	GENT	19	16	31	7	48	4	**16**
SI	LJUBLJANA	8	11	43	31	3	29	**17**
NL	MAASTRICHT	26	18	17	1	43	14	**18**
SE	JOENKOEPING	36	10	7	34	22	26	**19**
BE	BRUGGE	23	20	29	18	44	2	**20**
NL	ENSCHEDE	31	17	16	4	35	23	**21**
DE	GOETTINGEN	11	34	20	12	15	31	**22**
SE	UMEAA	39	5	10	36	46	10	**23**
DE	REGENSBURG	9	40	27	19	38	22	**24**
FR	DIJON	38	29	22	26	9	25	**25**
FR	NANCY	41	31	23	25	10	20	**26**
DE	TRIER	21	44	19	10	18	33	**27**
FR	CLERMONT-FERRAND	33	33	26	29	7	27	**28**
FR	POITIERS	48	37	28	33	8	15	**29**
SI	MARIBOR	49	21	37	40	2	32	**30**
IE	CORK	2	26	25	45	66	21	**31**
DE	ERFURT	32	47	21	13	21	45	**32**

Country	City	Smart Economy	Smart People	Smart Governance	Smart Mobility	Smart Environment	Smart Living	Total Rank
DE	MAGDEBURG	47	50	35	22	17	39	**33**
DE	KIEL	45	45	48	16	23	38	**34**
HR	ZAGREB	34	24	32	39	36	42	**35**
UK	CARDIFF	13	39	44	38	60	30	**36**
UK	LEICESTER	3	42	49	32	64	40	**37**
UK	PORTSMOUTH	7	38	47	35	63	43	**38**
UK	ABERDEEN	10	28	42	42	67	35	**39**
EE	TARTU	40	15	30	47	49	60	**40**
ES	PAMPLONA	22	48	39	51	32	41	**41**
CZ	PLZEN	43	49	61	30	54	28	**42**
ES	VALLADOLID	44	53	34	54	24	46	**43**
CZ	USTI NAD LABEM	54	51	55	23	55	36	**44**
IT	TRENTO	20	57	24	65	30	48	**45**
PT	COIMBRA	52	63	54	49	16	37	**46**
SK	NITRA	62	46	51	52	19	44	**47**
PL	RZESZOW	69	19	53	41	56	50	**48**
IT	TRIESTE	12	61	40	67	45	57	**49**
ES	OVIEDO	37	55	38	44	68	34	**50**
IT	ANCONA	35	59	36	68	34	49	**51**
IT	PERUGIA	42	54	41	66	42	51	**52**
PL	BIALYSTOK	67	22	59	56	47	55	**53**
SK	KOSICE	66	43	50	48	53	52	**54**
RO	TIMISOARA	50	64	64	62	4	59	**55**
SK	BANSKA BYSTRICA	70	41	52	53	58	47	**56**
PL	BYDGOSZCZ	68	27	57	46	52	61	**57**
GR	PATRAI	59	58	46	60	5	67	**58**
LT	KAUNAS	55	36	66	55	27	65	**59**
GR	LARISA	61	60	45	63	6	66	**60**
HU	GYOR	46	68	62	37	41	63	**61**
PL	SZCZECIN	65	52	58	43	59	56	**62**
RO	SIBIU	57	65	60	64	13	62	**63**
PL	KIELCE	63	56	56	57	62	54	**64**
HU	PECS	56	62	65	58	65	53	**65**
LV	LIEPAJA	60	12	63	61	61	70	**66**
HU	MISKOLC	58	67	67	50	70	58	**67**
RO	CRAIOVA	64	66	68	70	33	64	**68**
BG	PLEVEN	51	70	69	69	57	69	**69**
BG	RUSE	53	69	70	59	69	68	**70**

Table 3: *Outputs of Ranking Of European Medium-Sized Smart Cities (Giffinger et al., 2007).*

As it can be seen in Table 3, the top ratings have been achieved by the cities belonging to the Scandinavia and Benelux regions together with Austrian cities, with the sole exception of Ljubljana and Montpellier.

On the other hand, the cities that obtained the lowest ratings are those belonging to the new member states of the European Union, such as Ruse and Pleven (Bulgaria), Craiova (Romania) and Miskolc (Hungary).

This situation, in broad terms, is reflected by the ratings of the main characteristics of each city, but with some differences. Besides Ljubljana, Linz and Luxemburg, the best ratings in Smart Economy were obtained by British, Danish, German, Dutch and Irish cities. Dutch cities, together with Scandinavian cities and Luxemburg achieved the best ratings in Smart people. The best ratings in Smart Governance had been achieved by Austrian and Scandinavian cities. Concerning Smart Mobility, the best cities are those from Denmark and Benelux countries. The best rankings in Smart Environment, unlike the other characteristics, had been gained by French, Slovenian, Greek and Romanian cities. Finally, Smart Living is led by Scandinavian, Belgian, Austrian cities and Luxembourg.

However, with regard to the situation in Italy, only four Italian cities were included in the ranking by the researchers of the Vienna University of Technologies. These cities are:

- Trento, ranked 45th;
- Trieste, ranked 49th;
- Ancona, ranked 51th;
- Perugia, ranked 52th.

As we can see, unfortunately all the four cities can be found in the lower part of the ranking, in a close range between the 45^{th} and the 52^{th} positions. The performances of each city in the main characteristics reflect the position of the city in the ranking, with two exceptions. The first one concerns the important dimension of the Smart Economy, in fact Trento and Trieste are positioned in the top of the ranking, respectively in 20^{th} and 12^{th} position. The second exception concerns the bad rating achieved by all the four Italian cities: in fact Trento, Perugia, Trieste and Ancona can be found at the very bottom of the ranking, holding respectively the 65^{th}, the 66^{th}, the 67^{th} and the 68^{th} position.

Finally, it is worth to notice that the situation slightly improved in the recent years, in fact in the latest version of the ranking, released in 2015, three more Italian cities were added (Padova, Venezia and Verona).

IESE City In Motion Index (CIMI)

IESE City In Motion Index (CIMI) is a work published every year (the 2018 edition is the fifth one) by the IESE Business School of the University of Navarra. Due to the high level of global competition among smart cities, the importance of the capability to perform correctly the strategic planning process has considerably increased over the years, as well as the need for tools and instruments in order to support this activity.

Thus, the ambitious and foremost aim of the Cities In Motion Index is not just to provide a city-ranking but also to build a solid system of indicators with regard to characteristics, quality, comparability and objectivity of the information.

The IESE ranking is conceived to provide public and local administrations with a robust tool in order to be successful in the strategic planning process. In fact, nowadays it is becoming more and more important for smart cities to be able to identify firstly a central objective that has to be reached and then, models of development and systems of policies in order to achieve to it.

By taking into account all the actors involved in the urban ecosystem, the CIMI is also intended to enable the city to capitalize the advantages of networking, such as: the constant communication and the convergence of all the participants on the same target, the achievement of a higher level of transparency and better public policies, a proper recognition of the needs of the community and, last but not least, the implementation of long terms collaboration between private enterprises and the public administration.

The 2018 edition of the ranking includes 165 cities, among which 74 are capitals, representing 80 countries belonging to all the inhabited continents.

Each city has been evaluated both according to its performances in 9 dimensions that have been selected by the researchers and according to a synthetic indicator that is given by the weighted aggregation of all the dimensions and their indicators. The nine dimensions elaborated by the developers are: human capital, social cohesion, economy, governance, the environment, mobility and transportation, urban planning, international outreach and, finally, technology. However, both the dimensions and the system of the indicators on which they are based, will be treated in the next paragraph.

Table 4 shows the cities ranked by the CIMI according to their performance in each of the key dimensions and according to their synthetic indicator. The abbreviation employed are: "EC." for Economy, "H. C." for Human Capital, "S. C." for Social Cohesion, "EN." for

Environment, “G.” for Governance, “U. P.” for Urban Planning, “I. O.” for International Outreach, “T.” for Technology, “M. & T.” for Mobility and Transportation, “Rnk” for ranking position and “CIMI” for the score of the synthetic indicator.The measurement of the performance of the synthetic indicator is expressed as follows: high performance (H) has been assigned to cities with an index greater than 90, relatively high (RH) has been given to cities with an index between 90 and 60, average (A) has been obtained by cities with an index between 60 and 45 and, finally, low (L) has been assigned to cities with an index lower than 45. The evaluation of the performance of the synthetic indicator has been expressed through different colors: green for high, light green for relatively high, yellow for average and orange for low. The Italian cities are highlighted.

City	EC.	H. C.	S. C.	EN.	G.	U. P.	I. O.	T.	M. & T.	Rnk	CIMI
New York	1	4	109	99	38	1	3	5	4	1	100
London	4	1	68	40	5	7	2	6	2	2	99.27
Paris	7	8	87	49	43	3	1	12	1	3	90.20
Tokyo	2	5	48	11	40	32	17	27	22	4	84.38
Reykjavik	27	83	47	1	27	66	121	7	7	5	83.26
Singapore	13	39	90	10	8	39	5	2	63	6	79.52
Seoul	15	11	38	25	22	40	20	10	3	7	79.21
Toronto	28	24	28	55	4	2	25	16	68	8	78.16
Honk Hong	19	12	147	21	16	10	16	1	87	9	77.48
Amsterdam	36	46	26	36	23	13	6	3	13	10	77.44
Berlin	66	7	3	54	14	49	4	33	6	11	76.34
Melbourne	34	18	8	26	2	19	10	48	38	12	74.91
Copenhagen	12	54	23	3	13	90	32	20	43	13	74.55
Chicago	10	10	96	127	46	5	9	28	42	14	73.55
Sydney	35	15	20	22	26	17	21	8	76	15	73.50
Stockholm	5	55	64	8	19	45	36	25	44	16	73.29
Los Angeles	3	2	79	144	7	23	11	38	112	17	72.80
Wellington	22	85	15	2	25	14	132	62	15	18	71.64
Vienna	72	31	36	18	18	41	8	23	14	19	71.51
Washington	11	6	72	128	21	12	49	32	41	20	70.31
Boston	14	3	61	118	12	30	55	39	77	21	69.39
Helsinki	32	57	1	12	6	61	50	55	67	22	69.17
Oslo	17	62	21	13	51	48	64	24	78	23	68.14
Zurich	24	40	4	24	9	97	62	31	75	24	68.04
Madrid	64	34	53	50	34	37	19	21	9	25	67.76
Barcelona	78	37	86	66	15	16	14	15	12	26	67.53
San Francisco	6	13	75	110	70	28	41	14	98	27	67.31
Auckland	18	87	27	14	52	27	70	65	69	28	66.33
Bern	47	72	2	73	1	108	131	107	31	29	66.12
Dublin	16	80	22	35	45	75	44	17	100	30	65.63
Hamburg	57	27	33	67	31	44	48	53	11	31	65.10

City	EC.	H. C.	S. C.	EN.	G.	U. P.	I. O.	T.	M. & T.	Rnk	CIMI
Geneva	31	70	25	68	3	93	80	13	54	32	64.96
Göteborg	21	64	62	19	32	76	104	73	20	33	64.95
Basel	44	59	5	41	11	100	58	70	18	34	64.88
Ottawa	52	38	14	59	10	8	109	78	71	35	64.79
Vancouver	42	45	37	78	35	4	43	44	105	36	64.78
Munich	38	42	9	72	67	72	42	69	8	37	64.42
Montreal	51	51	39	63	24	9	23	118	80	38	64.42
Houston	8	17	59	146	44	25	29	29	107	39	64.36
Prague	82	61	31	23	60	94	27	18	66	40	63.85
Dallas	9	19	81	134	57	55	45	66	104	41	61.70
Frankfurt	45	32	67	93	81	29	34	94	29	42	61.61
Rotterdam	75	58	18	56	82	11	92	61	21	43	60.62
Lyon	43	60	45	52	63	38	67	101	36	44	60.49
Milan	69	35	92	57	104	47	46	71	16	45	60.06
Philadelphia	20	14	93	143	62	42	59	63	85	46	59.70
San Diego	25	23	80	136	17	53	73	19	113	47	59.34
Brussels	65	95	69	47	71	59	53	45	19	48	59.01
Riga	84	78	78	5	72	24	106	49	47	49	58.98
Tallinn	83	84	54	4	96	26	126	30	59	50	58.97
Miami	29	20	107	132	89	46	22	46	90	51	58.72
Lisbon	88	66	77	9	74	95	33	41	93	52	58.61
Budapest	110	52	101	17	64	70	35	34	65	53	58.55
Cologne	67	47	19	98	37	118	54	60	55	54	58.37
Stuttgart	49	53	13	64	68	113	79	116	45	55	57.94
Osaka	41	49	60	30	83	104	74	96	84	56	57.43
Shanghai	60	16	148	149	30	56	26	52	5	57	57.33
Birmingham	53	22	29	74	41	63	98	90	116	58	56.95
Manchester	56	21	30	104	58	82	65	75	108	59	56.76
Dubai	54	130	44	151	33	112	13	4	102	60	56.70
Vilnius	91	68	98	16	39	52	114	84	40	61	56.57
San Antonio	23	26	84	133	97	57	101	42	79	62	56.50
Valencia	98	97	50	43	20	60	112	74	25	63	56.41
Warsaw	108	65	58	83	50	15	30	114	58	64	56.33
Eindhoven	58	73	7	113	49	21	162	51	60	65	56.30
Rome	76	50	120	107	69	129	15	50	23	66	56.23
Bratislava	74	81	16	32	42	64	90	131	91	67	56.18
Glasgow	59	36	35	75	56	91	69	67	119	68	55.87
Anterp	80	99	32	45	117	33	123	85	17	69	55.77
Moscow	105	9	146	101	36	22	51	80	70	70	55.50
Nagoya	46	56	40	20	73	102	133	109	118	71	55.29
Tel Aviv	48	116	76	38	79	31	103	37	110	72	55.25
Linz	73	76	6	37	75	107	157	98	46	73	54.85
Ljubljana	89	96	17	34	111	73	111	43	56	74	54.72
Phoenix	37	33	70	138	94	65	115	92	37	75	54.72
Buenos Aires	151	43	94	33	29	18	24	126	96	76	54.68
Baltimore	33	28	97	139	47	51	105	86	99	77	54.50

City	EC.	H. C.	S. C.	EN.	G.	U. P.	I. O.	T.	M. & T.	Rnk	CIMI
Beijing	50	29	129	160	76	111	12	57	10	78	54.20
Nice	71	63	55	69	90	85	87	81	82	79	54.15
Marseille	63	82	88	87	78	68	75	122	49	80	53.47
Leeds	62	30	24	91	53	96	146	106	140	81	53.10
Liverpool	61	48	10	116	59	103	127	95	122	82	53.06
Zagreb	126	108	43	27	55	80	119	56	94	83	52.31
Lille	70	88	66	84	120	77	83	123	39	84	52.09
Seville	116	98	74	77	105	20	95	105	33	85	51.96
Santiago	122	91	91	28	107	62	78	77	72	86	51.45
Kuala Lampur	81	120	115	85	102	99	40	79	48	87	51.38
Porto	106	126	83	15	112	98	38	130	120	88	51.32
Málaga	123	107	51	89	85	83	99	87	26	89	50.44
Bangkok	77	123	102	135	136	50	7	59	114	90	50.34
Duisburg	86	67	11	109	113	123	100	144	51	91	50.19
Palma de Mallorca	99	114	82	96	88	71	96	47	50	92	49.96
Zaragoza	102	93	71	106	101	67	130	82	28	93	49.82
Panama City	79	75	110	42	126	121	72	36	125	94	49.77
Murcia	100	110	56	111	93	43	156	104	24	95	49.76
Nottingham	68	41	34	119	65	105	160	93	136	96	49.26
Abu Dhabi	26	149	12	162	87	131	71	9	64	97	49.22
Florence	92	77	100	126	135	125	85	22	30	98	48.88
Valladolid	113	102	73	51	95	81	159	129	53	99	48.57
Montevideo	131	136	117	7	54	78	97	83	129	100	48.25
Sofia	128	79	95	79	61	138	108	68	73	101	48.10
San José	107	152	108	6	28	135	89	91	153	102	48.08
Bilbao	96	105	85	103	84	86	137	100	92	103	47.97
Vigo	117	117	63	48	123	79	154	124	74	104	47.82
A Coruña	111	113	89	70	128	58	161	120	52	105	46.45
Turin	101	71	106	123	110	92	124	111	34	106	46.39
Mexico City	94	44	116	147	91	54	37	146	86	107	46.35
Minsk	150	74	42	46	131	110	102	125	81	108	46.16
Guangzhou	55	92	121	152	119	124	56	110	27	109	45.78
Belgrade	130	106	140	31	99	89	84	97	97	110	45.73
Doha	30	145	46	158	124	117	88	11	126	111	45.69
Tbilisi	104	125	125	39	100	130	116	108	103	112	45.69
Kiev	148	86	157	121	103	6	60	76	83	113	45.22
Istanbul	87	118	155	124	139	106	18	26	124	114	44.98
Shenzhen	39	104	135	150	137	143	66	121	32	115	44.84
São Paulo	155	103	145	90	121	34	28	72	88	116	44.63
Bogota	124	90	143	62	48	136	68	103	151	117	44.10
Almaty	146	121	49	100	147	84	152	115	35	118	43.73
Naples	119	89	114	105	144	88	94	136	101	119	43.59
Ankara	125	100	111	137	127	87	117	112	57	120	43.57
Jerusalem	95	131	139	53	66	128	120	119	141	121	43.14
Athens	135	69	160	61	146	109	52	40	89	122	42.55

City	EC.	H. C.	S. C.	EN.	G.	U. P.	I. O.	T.	M. & T.	Rnk	CIMI
Saint Petersburg	137	25	137	125	92	115	61	113	127	123	42.37
Ho Chi Minh City	109	150	119	76	133	137	77	127	111	124	42.08
Skopje	112	148	133	81	109	122	147	99	117	125	42.04
Rio de Janeiro	160	94	154	102	77	36	47	88	133	126	41.89
Baku	141	112	127	60	153	142	135	89	106	127	40.92
Kuwait City	93	153	65	142	108	154	118	35	130	128	39.85
Medellín	132	128	124	71	116	126	113	153	121	129	39.53
Rosario	158	122	57	114	141	35	144	141	123	130	38.80
Lima	115	111	130	122	86	146	81	143	158	131	38.68
Sarajevo	153	115	151	95	130	69	143	135	62	132	38.60
Cordoba	156	124	52	108	152	74	145	139	131	133	37.59
Tunis	136	146	113	58	129	140	139	149	146	134	37.29
Curitiba	161	139	123	65	132	116	122	117	109	135	37.09
Jakarta	114	133	126	140	114	153	31	132	164	136	36.56
Cali	139	135	99	80	122	133	153	160	148	137	36.08
Brasilia	163	138	144	82	125	127	91	142	61	138	36.05
Amman	145	157	103	115	106	149	138	64	160	139	35.69
Quito	157	127	105	88	160	132	107	133	128	140	35.57
Guatemala City	144	162	118	44	134	157	93	158	142	141	35.23
Novosibirsk	142	119	128	131	118	141	129	148	138	142	34.48
Cape Town	143	134	156	117	98	148	76	138	155	143	34.30
Manama	90	142	41	159	145	165	151	58	95	144	33.30
Santa Cruz	140	143	152	29	158	156	155	150	137	145	32.97
Manila	121	141	122	153	143	152	39	147	162	146	32.73
Salvador	164	129	142	86	140	120	134	152	132	147	31.65
Casablanca	134	164	131	130	159	150	110	102	147	148	31.26
Tianjin	40	109	134	165	150	139	150	134	115	149	30.61
Guayaquil	159	144	104	92	161	144	149	157	152	150	30.35
Belo Horizonte	162	132	136	120	142	134	136	140	149	151	30.21
La Paz	152	147	149	94	148	147	141	162	145	152	30.08
Riyadh	85	155	112	164	80	158	128	54	135	153	29.13
Santo Domingo	97	161	164	145	155	114	125	151	134	154	29.10
Rabat	147	158	150	112	157	151	158	155	156	155	28.12
Johannesburg	149	140	161	141	115	145	148	145	143	156	27.42
Cairo	129	137	158	154	162	119	86	128	159	157	27.24
Mumbai	127	154	138	156	138	160	57	137	161	158	26.67
New Delhi	103	151	141	163	149	163	63	156	154	159	26.60
Douala	138	156	132	97	164	159	165	163	144	160	26.52
Nairobi	120	160	162	148	154	155	140	159	163	161	25.97
Caracas	165	101	159	129	156	101	82	165	139	162	21.38
Kolkata	133	165	153	157	151	161	142	161	165	163	21.14
Lagos	154	159	163	155	165	162	164	164	157	164	20.41
Karachi	118	163	165	161	163	164	163	154	150	165	17.23

Table 4: *Outputs of the IESE City In Motion Index (IESE, 2018).*

It is interesting to notice that 12 of the top 25 cities are located in Europe and in particular the second and the third positions are occupied by London and Paris, while three are in Oceania, four are in Asia and six are in North America. While of the 30 top cities in the ranking, half are European and six are North American.

Concerning the synthetic indicator, the performances of 45 cities are rated high (H) or relatively high (RH), 68 cities have average (A) performances and 52 have low (L) performances, which corresponds respectively to 27.27%, 41.21% and 31.52%.

Looking closer at the top the ranking, it also interesting to notice that many smart city did not have homogenous performances in all the dimensions. For example, New York and London, which gained respectively the first and second positions of the ranking, showed good performances in many dimensions but had bad or less than average performances in social cohesion and environment.

Table 5 helps the reader in the comprehension of the ranking by highlighting the top 5 positions of the CIMI with respect to the nine key dimensions.

	1st Position	2nd Position	3rd Position	4th Position	5th Position
Economy	New York	Tokyo	Los Angeles	London	Stockholm
Human Capital	London	Los Angeles	Boston	New York	Tokyo
Social Cohesion	Helsinki	Bern	Berlin	Zurich	Basel
The Environment	Reykjavik	Wellington	Copenhagen	Tallinn	Riga
Governance	Bern	Melbourne	Geneva	Toronto	London
Urban Planning	New York	Toronto	Paris	Vancouver	Chicago
International Outreach	Paris	London	New York	Berlin	Singapore
Technology	Honk Kong	Singapore	Amsterdam	Dubai	New York
Mobility And Transportation	Paris	London	Seoul	New York	Shanghai

Table 5: *Top 5 positions of the CIMI with respect to the nine key dimensions. Adapted from: IESE City In Motion Index (IESE, 2018).*

With respect to the Italian situation, only five Italian cities have been included in the CIMI:

- Milan, ranked 45th and RH;
- Rome, ranked 66th and A;
- Florence, ranked 98th and A;

- Turin, ranked 106th and A;
- Naples, ranked 119th and L.

As it can be seen in Table 4, only Milan is among the cities with relatively high (RH) performances in the synthetic indicator, while the majority of the Italian cities (Rome, Florence and Turin) are rated average (H) and only Naples is rated low (L).

One the positive side, according to the developers of the CIMI, the city of Milan has gained nine positions with respect to the two previous editions of the ranking, passing from the 58th to the 45th positions

Unfortunately none of the Italian cities appears in the top 5 positions of any of the nine dimensions, as showed in Table 5. Among the Italian cities Milan is the one with the best performances, and particularly in mobility and transportation and human capital (respectively 16th and 35th positions) while it has a bad performances in governance and social cohesion (respectively 104th and 92th positions).

The city of Rome instead achieved good results in international outreach and mobility and transportation (15th and 23th positions) and bad results in environment, social cohesion and urban planning (respectively 107th, 120th and 129th). Despite having very bad performances in environment, governance and urban planning (126th, 135th and 125th), Florence achieved good results in technology and mobility and transportation (22th and 30th). Mobility and transportation is also the only dimension in which the city of Turin obtained a very good result with the 34th position.

Human capital, urban planning and international outreach, instead, are the dimensions in which the city of Naples achieved its best positions, respectively 89th, 88th and 94th.

From these data it can be deducted that in general terms Italian cities achieved their best performances in mobility and transportation with the sole exception of Naples. On the contrary, it is not possible to define a general trend concerning the dimensions in which Italian cities collected the poorest performances.

2017 Smart City Index

2017 Smart City Index is a smart city ranking developed in 2017 by EasyPark, which is a private company that provides mainly apps for mobile telecommunications services.

The aim of the developers was to produce a ranking that would have taken into account sustainability, digitalization and the use of ICT as crucial factors for the spread of the smart cities. In particular, they tried to consider the impact of Big Data as a problem-solving tool for the problems of the cities.

The cities has been evaluated according to their performances 19 factors, which are composed by 39 indicators. These factors, according to the developers, represent the most important aspects of a smart city and they are part of seven main categories: transport and mobility, sustainability, governance, innovation economy, digitalization, living standard and expert perception. The indicators, the factors and the main categories are reported in detail in the next paragraph.

The selection of the cities suitable to be included in the index followed a methodology that encompassed different steps. Firstly, during a preliminary phase, 500 cities from all over the world with medium and high development have been selected, according to the UN prosperity list, the European Commission’s Digital City Index and the Human Development Index.

The final list of 100 cities has been determined subsequently by analyzing the 500 cities with respect to the 19 factors, trying to cover a wide range of regions and to take into account all the possible points of interest such as capital and financial centers.

The complete ranking of 2017 Smart City Index is showed by Table 6 toghter with the total score achieved by each city.

Tables 7, 8, 9 and 10 show the shows the factors’ partial rankings of the 2017 Smart City Index respectively of Milan, Turin, Rome and Naples.

Ranking Position	City	Score
1	Copenhagen	8,24
2	Singapore	7,83
3	Stockholm	7,82
4	Zurich	7,75
5	Boston	7,70
6	Tokyo	7,59
7	San Francisco	7,55
8	Amsterdam	7,54
9	Geneva	7,53
10	Melbourne	7,51
11	Vancouver	7,47
12	Sydney	7,43
13	Berlin	7,39

Ranking Position	City	Score
51	Madrid	6,32
52	Osaka	6,24
53	Barcelona	6,23
54	Abu Dhabi	6,07
55	Birmingham	6,06
56	Bochum	6,00
57	Taipei	5,96
58	Doha	5,87
59	Lyon	5,85
60	Milan	5,80
61	Adelaide	5,74
62	Brussels	5,64
63	Daejeon	5,48

Ranking Position	City	Score
14	Hamburg	7,36
15	Gothenburg	7,23
16	Montreal	7,22
17	London	7,18
18	Tel Aviv	7,15
19	Toronto	7,14
20	Paris	7,14
21	Seoul	7,13
22	Luxembourg	7,10
23	Helsinki	7,02
24	New York	6,99
25	Munich	6,99
26	Düsseldorf	6,98
27	Västerås	6,95
28	Washington DC	6,91
29	Bayreuth	6,87
30	Hannover	6,87
31	Cologne	6,84
32	Vienna	6,84
33	Frankfurt am Main	6,74
34	Olso	6,73
35	Philadelphia	6,72
36	Chicago	6,69
37	Trondheim	6,65
38	Dubai	6,65
39	Helsinborg	6,64
40	Ottawa	6,63
41	Perth	6,61
42	Dublin	6,59
43	Stavanger	6,58
44	Manama	6,50
45	Aarhus	6,49
46	Los Angeles	6,47
47	Stuttgart	6,40
48	Auckland	6,36
49	Espoo	6,35
50	Bergen	6,35

Ranking Position	City	Score
64	Lisbon	5,46
65	Leeds	5,32
66	Ljubljana	5,32
67	Tampere	5,30
68	Honk Kong	5,29
69	Turin	5,27
70	Reykjavik	5,23
71	Rome	5,19
72	Prague	5,14
73	Vilnius	5,13
74	Marseille	5,04
75	Riga	4,90
76	Tallin	4,75
77	Moscow	4,50
78	Panama City	4,49
79	Budapest	4,38
80	Sao Paulo	4,35
81	Beijing	4,31
82	Bratislava	4,21
83	Naples	4,21
84	Kuala Lumpur	4,17
85	Shanghai	4,12
86	Rio de Janeiro	4,07
87	Bucharest	4,00
88	St Petersburg	3,98
89	Warsaw	3,97
90	New Delhi	3,93
91	Athens	3,90
92	Cape Town	3,82
93	Mumbai	3,80
94	Sofia	3,78
95	Santiago	3,65
96	Buenos Aires	3,63
97	Medellin	3,62
98	Monterrey	3,54
99	Riyadh	3,47
100	Mexico City	3,19

Table 6: *Output of the 2017 Smart City Index (EasyPark Group website).*

Factor	Partial Score	Partial Ranking
Smart Parking	6,45	40
Car Sharing Services	8,18	20
Traffic	5,41	54
Public Transport	2,47	87
Clean Energy	7,66	25
Smart Building	7,75	28
Waste Disposal	5,76	48
Environmental Protection	7,06	34
Citizen Participation	6,17	43
Digitalization Of Government	1,87	91

Factor	Partial Score	Partial Ranking
Urban Planning	3,21	80
Education	7,23	34
Business Ecosystem	5,24	55
4G LTE	4,94	61
Intenet Speed	4,29	67
Wifi Hotspot	8,01	25
Smartphone Penetration	5,02	69
Living Standard	4,55	68
How The City is Becoming Smarter	6,50	62

Table 7: *Factors' partial rankings of the 2017 Smart City Index: Milan (EasyPark Group website)*

Factor	Partial Score	Partial Ranking
Smart Parking	6,56	37
Car Sharing Services	8,27	19
Traffic	7,84	24
Public Transport	2,47	88
Clean Energy	7,66	26
Smart Building	7,75	29
Waste Disposal	5,76	49
Environmental Protection	7,49	28
Citizen Participation	6,52	37
Digitalization Of Government	3,94	70

Factor	Partial Score	Partial Ranking
Urban Planning	5,94	51
Education	6,54	42
Business Ecosystem	2,30	88
4G LTE	3,40	77
Intenet Speed	2,47	87
Wifi Hotspot	3,51	76
Smartphone Penetration	5,02	70
Living Standard	4,29	70
How The City is Becoming Smarter	5,00	87

Table 8: *Factors' partial rankings of the 2017 Smart City Index: Turin. (EasyPark Group website)*

Factor	Partial Score	Partial Ranking
Smart Parking	6,14	45
Car Sharing Services	8,10	22
Traffic	2,73	84
Public Transport	1,52	95
Clean Energy	7,66	27
Smart Building	7,75	30
Waste Disposal	5,76	50
Environmental Protection	6,54	39
Citizen Participation	6,44	38
Digitalization Of Government	1,35	97

Factor	Partial Score	Partial Ranking
Urban Planning	6,82	40
Education	6,80	40
Business Ecosystem	2,47	86
4G LTE	3,31	78
Intenet Speed	2,38	88
Wifi Hotspot	6,71	43
Smartphone Penetration	5,02	71
Living Standard	3,42	78
How The City is Becoming Smarter	6,00	70

Table 9: *Factors' partial rankings of the 2017 Smart City Index: Rome. (EasyPark Group website)*

Factor	Partial Score	Partial Ranking
Smart Parking	3,47	82
Car Sharing Services	1,87	90
Traffic	4,55	62
Public Transport	2,47	89
Clean Energy	7,66	28
Smart Building	7,75	31
Waste Disposal	5,76	51
Environmental Protection	7,40	29
Citizen Participation	6,08	44
Digitalization Of Government	4,03	69

Factor	Partial Score	Partial Ranking
Urban Planning	3,29	78
Education	6,28	45
Business Ecosystem	1,78	94
4G LTE	3,74	74
Intenet Speed	2,64	85
Wifi Hotspot	2,21	90
Smartphone Penetration	5,02	72
Living Standard	3,70	75
How The City is Becoming Smarter	4,70	92

Table 10: *Factors' partial rankings of the 2017 Smart City Index: Naples. (EasyPark Group website)*

Half of the 20 top positions are occupied by European cities while three are Asian, five are North American and two are from Oceania. Unfortunately no Italian cities are among the top 20 positions, which are the vanguard of urban growth.

Four Italian cities have been included in the ranking and they are located in the lowest half of the ranking, ranging between the 60^{th} and the 83^{th} position. These cities are:

- Milan, ranked 60th;
- Turin, ranked 69th;
- Rome, ranked 71th ;
- Naples, ranked 83th.

The city of Milan holds the better position with respect to the Italian cities and it, together with Turin, is among those cities that are, according to EasyPark, making strides towards a digitalized infrastructure.

Turin and Milan (respectively Table 8 and Table 7) are, in fact, the only two Italian cities which appear in the top 20 position of a factor's performance: they both appear in the ranking of the "car sharing services" factor, respectively in the 19^{th} and in the 20^{th} position. Nevertheless, Milan obtained achieved a very bad position (90^{th}) in the performance of the "digitalization of Government" factor.

The other Italian cities instead are on the bottom of the ranking (especially Naples) and this means, according to the developers, that they are emerging smart cities which need still time to improve.

In particular, Rome is ranked 96^{th} (Table 9)in the "digitalization of Government" factor while Naples (Table 10) is ranked 91^{th} in the "expert perception" factor and 97^{th} in the "business ecosystem" factor.

Finally, it is interesting to notice that all the Italian cities achieved very poor results in the "public transport" factor with Milan ranked 87^{th}, Turin 88^{th}, Naples 89^{th} and Rome 95^{th}.

ICity Rate 2017

ICity Rate 2017 - La classifica delle città intelligenti italiane is a useful tool that provide an actual and updated overview of the current situation of the development of the smart city context in Italy and it is produced annually by the aforementioned FORUM PA.

Unlike the smart cities rankings previously described in this chapter, ICity rate 2017 is totally focused on Italian cities and it considers 106 provincial capitals ranked according to different parameters.

ICity rate 2017, differently from the previous editions, is strongly focused on the theme of the urban sustainability as a key element for the smart city development and, for this reason, many new parameters have been added. The theme of the sustainability has been addressed in 2015 by the United Nations Development Programme through the definition of the 2030 Agenda, which is an action plan based on the Sustainable Development Goals (SDGs). The SDGs are a collection of 17 global goals, subdivided into 169 targets, that cover social and economic development issues and that, according to the UN, should be met before 2030.

ICity rate, according to its developers, could be a useful tools able to help the cities and their administrators to dealt with some issues that characterize the Italian context, such as: lack of strategies and laws needed for the achievement of the goals and absence of a systemic vision which led inevitably to short-term policies that contradict each other.

The cities had been evaluated according to their performances in 15 main dimensions which encompasses 113 sub dimensions or indicators. The evaluation of these performances were subsequently aggregated and elaborated in order to produce the single indicator on which the total ranking is based.

The main categories are: governance and participation, legality and safety, research and innovation, digital transformation, culture and tourism, employment, economic growth, sustainable mobility, poverty, education, air quality and water efficiency, energy, green urban areas, soil and land, and finally waste. However the categories and their indicators will be reported in detail in the next paragraph.

Table 11 shows the complete ranking of the 106 cities with the respective scores obtained in the total single indicator, while Tables 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25 and 26 present the top and bottom 12 positions of the partial ranking relative to the performances achieved the cities in all the main categories.

Ranking Position	City	Score
1	Milan	599,1
2	Bologna	597,4
3	Florence	571,1
4	Venice	553,3
5	Trento	545,8
6	Bergamo	538,1
7	Turin	532,9
8	Ravenna	517,6
9	Parma	513,9
10	Modena	513,3
11	Reggio nell'Emilia	510,7

Ranking Position	City	Score
54	Alessandria	413,4
55	Macerata	412,4
56	Pesaro	411,0
57	Verbania	409,2
58	L'Aquila	405,7
59	Pistoia	401,7
60	Terni	400,5
61	Pescara	398,8
62	Asti	396,1
63	Massa	391,7
64	Grosseto	388,7

Ranking Position	City	Score
12	Padova	509,5
13	Pisa	503,3
14	Bolzano - Bozen	502,0
15	Trieste	500,5
16	Vicenza	499,7
17	Rome	499,6
18	Mantova	498,1
19	Monza	496,1
20	Ferrara	494,8
21	Genova	494,7
22	Rimini	492,2
23	Cremona	491,3
24	Verona	486,1
25	Forlì	484,5
26	Siena	482,4
27	Udine	479,3
28	Brescia	479,1
29	Treviso	475,9
30	Pordenone	475,4
31	Lecco	470,7
32	Como	467,6
33	Varese	465,0
34	Arezzo	464,6
35	Biella	463,6
36	Lodi	457,9
37	Novara	457,8
38	Pavia	457,2
39	Sondrio	457,2
40	Prato	449,5
41	Piacenza	447,8
42	Perugia	445,1
43	Gorizia	443,7
44	Ancona	442,9
45	Aosta	442,1
46	Belluno	439,4
47	Cagliari	437,9
48	Vercelli	436,3
49	Livorno	434,5
50	Lucca	430,9
51	Savona	427,4
52	Cuneo	426,2
53	La Spezia	423,1

Ranking Position	City	Score
65	Ascoli Piceno	386,8
66	Rovigo	381,6
67	Viterbo	375,9
68	Bari	375,8
69	Rieti	368,2
70	Matera	365,5
71	Lecce	359,4
72	Fermo	357,4
73	Frosinone	347,2
74	Teramo	344,1
75	Sassari	343,9
76	Imperia	342,6
77	Potenza	342,0
78	Latina	330,0
79	Salerno	316,5
80	Chieti	315,3
81	Oristano	315,0
82	Naples	314,4
83	Isernia	311,5
84	Siracusa	308,9
85	Andria	307,8
86	Messina	307,1
87	Palermo	303,6
88	Brindisi	297,7
89	Campobasso	292,0
90	Nuoro	285,4
91	Avellino	283,3
92	Reggio di Calabria	283,0
93	Caserta	281,9
94	Ragusa	281,5
95	Cosenza	278,4
96	Taranto	278,0
97	Benevento	276,0
98	Foggia	270,8
99	Catania	269,5
100	Enna	260,2
101	Catanzaro	255,8
102	Crotone	242,6
103	Agrigento	230,1
104	Caltanissetta	221,4
105	Vibo Valentia	214,6
106	Trapani	211,3

***Table 11:** Outputs of ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Parma	739,65
2	Bolzano - Bozen	722,67
3	Udine	711,34
4	Trieste	698,00
5	Gorizia	685,37
6	Bologna	685,33
7	Pordenone	677,34
8	Belluno	675,32
9	Modena	667,70
10	Trento	656,40
11	Cremona	646,07
12	Aosta	643,73

Ranking Position	City'	Score
95	Viterbo	402,64
96	Ragusa	388,19
97	Catania	386,58
98	Cosenza	377,04
99	Naples	375,13
100	Trapani	372,14
101	Caltanissetta	365,33
102	Andria	364,60
103	Taranto	363,76
104	Brindisi	360,67
105	Vibo Valentia	349,45
106	Reggio di Calabria	308,76

Table 12: *Top and bottom 12 positions relative to poverty in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Vicenza	831,3
2	Rovigo	826,2
3	Padova	816,1
4	Florence	799,6
5	Treviso	772,8
6	Venice	764,4
7	Viterbo	720,9
8	Pisa	719,9
9	Perugia	686,6
10	Monza	680,2
11	Pescara	675,8
12	Siena	671,6

Ranking Position	City'	Score
95	Agrigento	393,3
96	Enna	392,8
97	Andria	373,7
98	Chieti	373,7
99	Nuoro	366,8
100	Ragusa	366,0
101	Crotone	342,9
102	Palermo	323,3
103	Verbania	318,0
104	Catania	243,3
105	Caltanissetta	231,4
106	Imperia	221,3

Table 13: *Top and bottom 12 positions relative to education in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Viterbo	878,9
2	Aosta	851,3
3	Trapani	833,7
4	Brindisi	832,5
5	Ascoli Piceno	832,4
6	Livorno	829,4
7	Vibo Valentia	824,8
8	Grosseto	819,3
9	Belluno	813,3
10	Oristano	811,9
11	Siena	811,2
12	Macerata	807,6

Ranking Position	City'	Score
95	Treviso	527,3
96	Messina	516,4
97	Monza	510,5
98	Milan	505,1
99	Caltanissetta	497,8
100	Agrigento	481,9
101	Lodi	457,5
102	Como	454,8
103	Frosinone	429,7
104	Catania	411,7
105	Palermo	351,3
106	Benevento	347,7

Table 14: *Top and bottom 12 positions relative to air quality and water efficiency in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Bologna	897,3
2	Verona	873,6
3	Vicenza	857,3
4	Florence	831,6
5	Venice	825,7
6	Trieste	820,9
7	Udine	784,2
8	Padova	772,2
9	Turin	770,5
10	Reggio nell'Emilia	769,9
11	Prato	768,6
12	Livorno	758,7

Ranking Position	City'	Score
95	Siracusa	490,5
96	Catania	454,7
97	Reggio di Calabria	417,3
98	Catanzaro	374,2
99	Vibo Valentia	370,5
100	Benevento	329,6
101	Foggia	320,4
102	Crotone	304,2
103	Trapani	281,2
104	Agrigento	275,9
105	Caserta	216,6
106	Taranto	135,9

Table 15: *Top and bottom 12 positions relative to energy in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Milan	901,0
2	Modena	526,9
3	Bergamo	526,8
4	Bologna	520,4
5	Floence	484,1
6	Vicenza	483,8
7	Brescia	472,0
8	Bolzano - Bozen	467,8
9	Padova	459,4
10	Treviso	455,7
11	Reggio nell'Emilia	455,0
12	Pordenone	446,7

Ranking Position	City'	Score
95	Oristano	147,8
96	Foggia	147,7
97	Messina	147,5
98	Trapani	140,1
99	Crotone	139,1
100	Brindisi	136,7
101	Agrigento	130,8
102	Reggio di Calabria	130,5
103	Taranto	127,9
104	Vibo Valentia	124,7
105	Enna	114,8
106	Andria	73,8

Table 16: *Top and bottom 12 positions relative to economic growth in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Milan	834,7
2	Bologna	830,8
3	Florence	816,5
4	Pisa	809,6
5	Bolzano - Bozen	803,4
6	Aosta	798,2
7	Siena	793,4
8	Trieste	779,8
9	Monza	776,6
10	Biella	774,1
11	Parma	768,0
12	Ravenna	761,8

Ranking Position	City'	Score
95	Naples	264,2
96	Vibo Valentia	262,1
97	Palermo	261,6
98	Catania	254,7
99	Reggio di Calabria	252,4
100	Agrigento	250,6
101	Caltanissetta	241,3
102	Caserta	236,7
103	Trapani	232,3
104	Enna	219,7
105	Andria	218,1
106	Foggia	190,5

Table 17: *Top and bottom 12 positions relative to employment in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Florence	539,1
2	Milan	475,3
3	Venice	467,1
4	Siena	386,6
5	Roma	386,5
6	Turin	379,2
7	Vicenza	376,9
8	Verona	363,9
9	Trento	349,3
10	Bologna	337,2
11	Rimini	335,8
12	Genova	324,6

Ranking Position	City'	Score
95	Vibo Valentia	73,4
96	Agrigento	73,2
97	Isernia	72,2
98	Brindisi	71,1
99	Taranto	70,0
100	Ragusa	67,2
101	Reggio di Calabria	63,7
102	Nuoro	51,7
103	Foggia	50,1
104	Enna	41,7
105	Crotone	34,5
106	Caltanissetta	33,6

Table 18: *Top and bottom 12 positions relative to culture and tourism in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Milan	743,1
2	Brescia	683,6
3	Bergamo	680,2
4	Ferrara	678,8
5	Monza	672,7
6	Modena	654,4
7	Lecco	636,8
8	Lodi	634,5
9	Rieti	626,0
10	Cremona	620,2
11	Novara	619,1
12	Bologna	616,8

Ranking Position	City'	Score
95	Palermo	139,6
96	Trapani	139,3
97	Agrigento	139,3
98	Enna	139,3
99	Caltanissetta	139,3
100	Catanzaro	124,1
101	Crotone	118,5
102	Vibo Valentia	118,2
103	Reggio di Calabria	115,4
104	Cosenza	114,4
105	Campobasso	70,4
106	Isernia	69,1

Table 19: *Top and bottom 12 positions relative to research & innovation in ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Milan	715,2
2	Bologna	678,8
3	Roma	618,6
4	Genova	599,6
5	Florence	578,5
6	Turin	548,3
7	Modena	523,6
8	Livorno	482,2
9	Reggio nell'Emilia	473,9
10	Venice	466,2
11	Bergamo	463,4
12	Prato	455,5

Ranking Position	City'	Score
95	Nuoro	123,1
96	Ascoli Piceno	117,3
97	Imperia	107,0
98	Oristano	101,6
99	Caltanissetta	101,3
100	Fermo	100,7
101	Campobasso	99,8
102	Rieti	97,9
103	Agrigento	93,3
104	Chieti	88,7
105	Avellino	84,3
106	Trapani	75,5

Table 20: *Top and bottom 12 positions relative to digital transformation in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Milan	548,2
2	Turin	427,6
3	Venice	422,0
4	Florence	393,2
5	Bergamo	391,4
6	Brescia	379,9
7	Padova	358,3
8	Parma	352,3
9	Bologna	350,6
10	Mantova	347,0
11	Modena	343,1
12	Lodi	337,3

Ranking Position	City'	Score
95	Trapani	136,4
96	Matera	135,7
97	Salerno	129,7
98	Siracusa	126,5
99	Isernia	126,0
100	Vibo Valentia	120,3
101	Catania	120,3
102	Oristano	119,4
103	Agrigento	115,9
104	Caltanissetta	111,7
105	Enna	109,2
106	Nuoro	109,0

Table 21: *Top and bottom 12 positions relative to sustainable mobility in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Trento	772,0
2	Treviso	736,9
3	Belluno	711,8
4	Novara	706,0
5	Macerata	699,1
6	Pordenone	685,3
7	Asti	677,6
8	Benevento	664,6
9	Oristano	662,1
10	Verbania	657,5
11	Mantova	651,6
12	Parma	650,8

Ranking Position	City'	Score
95	Siena	294,9
96	Campobasso	294,6
97	Catanzaro	292,4
98	Cagliari	279,4
99	Massa	279,1
100	Agrigento	268,9
101	Pisa	260,5
102	Vibo Valentia	249,4
103	Foggia	236,6
104	Crotone	220,8
105	Trapani	203,7
106	Catania	179,6

Table 22: *Top and bottom 12 positions relative to waste in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Venice	578,8
2	Messina	536,9
3	Matera	514,2
4	Pisa	473,6
5	Sondrio	465,6
6	Cagliari	430,4
7	Varese	417,9
8	Lodi	401,4
9	Biella	369,7
10	Vercelli	367,1
11	Trento	366,6
12	Palermo	359,8

Ranking Position	City'	Score
95	Rovigo	78,2
96	Cosenza	77,3
97	Avellino	77,3
98	Benevento	74,1
99	Chieti	68,0
100	Lecce	60,7
101	Nuoro	53,4
102	Ragusa	36,4
103	Catanzaro	29,9
104	Latina	23,9
105	Trapani	21,5
106	Vibo Valentia	12,9

Table 23: *Top and bottom 12 positions relative to green urban areas in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Ragusa	961,6
2	Grosseto	902,1
3	L'Aquila	893,7
4	Parma	876,4
5	Lecce	875,7
6	Alessandria	840,8
7	Ravenna	836,8
8	Rovigo	827,0
9	Reggio nell'Emilia	816,0
10	Pisa	808,6
11	Foggia	801,6
12	Fermo	788,3

Ranking Position	City'	Score
95	Agrigento	469,6
96	Caltanissetta	469,1
97	Milan	454,6
98	Turin	436,0
99	Caserta	424,6
100	Monza	396,6
101	Avellino	385,1
102	Salerno	374,8
103	Benevento	373,2
104	Messina	351,9
105	Palermo	322,3
106	Naples	193,5

Table 24: *Top and bottom 12 positions relative to soil and land in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Aosta	951,8
2	Sondrio	951,1
3	Biella	942,4
4	Bolzano - Bozen	942,3
5	Cuneo	940,8
6	Lodi	937,9
7	Udine	926,4
8	Belluno	916,9
9	Asti	916,4
10	Ferrara	914,3
11	Pordenone	913,3
12	Mantova	912,6

Ranking Position	City'	Score
95	Messina	689,7
96	Bari	670,0
97	Latina	666,0
98	Vibo Valentia	645,7
99	Cosenza	642,0
100	Palermo	619,7
101	Roma	614,9
102	Salerno	578,2
103	Foggia	575,8
104	Catania	552,7
105	Reggio di Calabria	479,8
106	Naples	345,9

Table 25: *Top and bottom 12 positions relative to legality and safety in the ICity Rate 2017 (FORUM PA, 2017).*

Ranking Position	City	Score
1	Bologna	692,2
2	Milan	655,3
3	Turin	611,8
4	Genova	608,0
5	Pisa	603,1
6	Bolzano - Bozen	591,2
7	Parma	589,4
8	Florence	587,1
9	Perugia	586,1
10	Bergamo	569,5
11	Brescia	559,3
12	Reggio nell'Emilia	556,5

Ranking Position	City'	Score
95	Cosenza	302,5
96	Avellino	302,4
97	Crotone	302,3
98	Enna	298,1
99	Isernia	294,0
100	Catania	289,4
101	Vibo Valentia	283,9
102	Reggio di Calabria	280,9
103	Frosinone	279,9
104	Agrigento	264,7
105	Caltanissetta	255,6
106	Andria	241,2

Table 26: *Top and bottom 12 positions relative to governance and participation in the ICity Rate 2017 (FORUM PA, 2017).*

It is interesting to notice that, according to the ranking, the Italian smart city situation is very polarized, with the smartest city concentrated in the North East and in the North West. The Centre is very close to the North, with the exception of Rome which, despite the improvement with respect to the previous editions, performs almost poorly in too many categories. The less smart cities can be found in the South.
Large cities and metropolis appear to be generally smarter and to have higher growth rate than medium centers. However, large cities performs very poorly in categories related to sustainability such as land and soil consumption and water and air quality and in the dimensions connected with safety and security.
On the contrary, in terms of sustainability, the medium cities of the Emilia-Romagna achieved good ratings.
Concerning the South, the cities of Sardinia are among the best, being Cagliari the smartest among the southern cities. Sicily, Calabria and Puglia are the Regions with the worst ratings in the ICity 2017.
A more detailed description of many of the performances of the cities of the ranking will be provided in Chapter 3.
It is also interesting to spend a couple of words to illustrate the situation concerning the partial rankings of each dimension, which in any case depict a situation similar to the one of the total ranking.
With regard to poverty (Table 12), the situation is very defined, with cities of Friuli Venezia Giulia, Emilia-Romagna, Trentino, Valle d'Aosta and partially Lombardy and Veneto that were addressing this issue by implementing the most effective polices.
The education dimension (Table 13), on the contrary, shows a very unpolarized situation: the top positions, which belongs to cities from the North East and the Tuscany, are closely followed by cities from the central Regions such as Pescara and Roma. The bottom of the ranking is also a mix of cities from different Regions, with Imperia that holds the lowest position.
Water efficiency concerns the dispersion of the water along the distribution systems and the sewage water treatment, while air quality is about compliance with the ceiling for emissions of PM10, PM2,5 and NO2 (Table 14).
The small and medium cities, independently from the Region to which they belong, have a considerably higher water efficiency, while cities like Cagliari, Messina, Bari, Messina and

Florence had an higher dispersion rate, which was respectively the 58,6%, 53,1%, 49,6%, 48,1% and 45,7%.

The city with worst air quality, considering all the indicators, is definitely Milan. In particular, besides Milan, the cities with biggest violations of the ceiling for emissions of PM10 are Turin and Venice. The emissions of PM10 for these cities are 30 times beyond the limits.

The cities with the highest emissions of PM2,5 are again Milan, Turin, Venice and Rome. Milan, Turin and Rome are also the cities with the highest emissions of NO2.

The energy efficiency performances appear to be of almost poor quality and very far from those suggested by the Sustainable Development Goals throughout Italy, with the exception of very few Northern cities, such as Bologna and Verona (Table 15).

For what concerns economic growth (Table 16), the top of the ranking is represented by the Northern cities, such as Milan, Modena, Bergamo and Bologna, while on the bottom there are the cities from the South. The cities belonging to the central Regions are in the middle of the ranking.

The employment rate appears to be high only for 12 cities on 106. The cities on the top of the ranking (Table 17) were Milan, Bologna and Florence and generally those from the North and from Tuscany, while the city from the South had very low employment rate.

The dimension related to tourism and culture takes into account tourists flows and the capability to generate and attract them. The cities more able to attract tourists (Table 18) are many large and medium cities such as Milan, Venice, Siena, Rome and Verona, while the cities in the South had still problems to valorize their heritage, landscapes and landmarks and, thus, they are on the bottom of the ranking.

The research and innovation dimension is dominated by the Northern cities and the top positions were held by Milan, Brescia, Bergamo and Ferrara (Table 19).

The digital transformation dimension concerns the diffusion of smart networks and the easy access to data and information. The large cities and metropolitan areas appears to be the sites where the digital transformation took place because of many factors, such as the availability of resources, competences and opportunities and the presence of demand and offer. Thus, the top cities of this partial ranking are Milan, Rome, Bologna, Genoa and Florence (Table 20).

The dimension of sustainable mobility is intended to evaluate the capability of the cities to elaborate sustainable models of urban mobility and to improve the accessibility of the territory.

On the top this partial ranking (Table 21) there are Milan, Turin, Venice and in general the cities of the Northern Regions, followed by those of the Central Regions. The lowest position are occupied by the Southern cities.

Waste management dimensions is evaluated according to both the production of waste per person and the recycling rate. The more virtuous cities, such as Trento, Treviso, Belluno and Macerata are again concentrated in North and in the Center (Table 22).

For what concerns the green urban areas (Table 23) the situation is completely different since the performances of the cities are not related to the Regions to which they belong. Green areas represent on average the 16,9% of the total surface of the Italian provincial capitals which corresponds to an average of 47,7 sqm for each inhabitant, and encompasses non wooded areas, gardens as well as green areas inside ancient districts. However, the latter value is considerably higher (more than 300 sqm per person) for the cities are on top o the partial ranking, such as Matera, Trento, Sondrio and Potenza. On the contrary, for the cities on the bottom the ranking, such as Vibo Valentia and Trapani, the average of sqm of green areas per person is lower than 3.

The soil and land dimension refers to the capability of the cities to counteract the soil sealing and to adopt policies against the soil consumption, in order to achieve the aim of Agenda 30 to reduce it 1,6 sqm per inhabitant by 2030. The best cities in this partial ranking are those of medium and small size, such as Ragusa, Grosseto and L'Aquila, while the worst ones are Naples, Salerno and Benevento (Table 24).

The best cities from the point of view of legality and safety (Table 25) are the small and medium cities concentrated in the North, and in particular, Aosta, Sondrio, Biella and Bolzano are on the top. The worst cities instead belong to the Southern Regions, such as for example Catania, Reggio di Calabria and Naples.

The governance and participation dimension is evaluated according to the capability of the local administrations to involve the citizens in the management of the cities and adopt policies for the social innovation. The cities that observe the best practices are mostly located in the Central and northern regions, and on the top there are Bologna, Milan, Turin and Genoa (Table 26).

Finally, in order to briefly recap the current situation of the Italian smart city context and its main issues, it can be useful to add the that, according to FORUM PA, the ICity rate 2017 highlights:

- that the delay concerning the implementation of sustainability policies is a common problem;
- that different approaches towards the development and the governance of different cities may lead to positive results, as exemplified by the three top cities (Milano, Bologna e Firenze);
- the importance of medium sized cities, especially in Emilia-Romagna;
- a serious delay of some parts of Italy compared to others. In fact, there is a huge gap between Rome and most of the cities of southern Italy, on one hand, and the cities of northern and centre Italy on the other hand.

2.3 Review Of Indicators Of Smartness In Ranking Systems

This paragraph is aimed at showing the presence of indicators that measures the quantity or the quality of the offer of smart innovative services in a smart city.

Thus, in this paragraph all the information included by the developers of the rankings concerning the lists of indicators, the methodologies and the sources for data extraction are presented. For each ranking the indicators directly related to the provision of smart services have been detected and highlighted.

Moreover, the diversity of the indicators of smartness employed by each ranking, provides the reader with a clear idea of the complexity and heterogeneity of the concept of smart city discussed in the first chapter and a better understanding of the dynamics of city rankings.

Ranking Of European Medium-Sized Smart Cities By The TU Wien

As already mentioned the 70 cities belonging to the sample have been evaluated according to the performances achieved in six main characteristics, or dimensions, that have been identified by the developers as smart economy, smart mobility, smart environment, smart people, smart living and smart governance. Each dimension is composed by many factors which in turn are related to many indicators of smartness: 31 factors and 74 indicators are considered on the whole.

These six characteristics are:

- **Smart Economy** that is linked to the factors and indicators of entrepreneurship, trademarks and economic image, integration in the local and global market, innovation, productivity and flexibility of the labour market and, of course, economic competitiveness;
- **Smart People** that refers to the quality of social interactions in the city, to the integration in the public life and to the qualification and education of its citizens and, thus, to the management of social and human capital;
- **Smart Governance** that is defined by the functioning of the administration, the public and social services for citizens and also by all the aspects of political participation;
- **Smart Mobility** that is related not only to the local and international accessibility and to the existence of safe, modern and sustainable transport system but also to the availability of an ICT-infrastructure;
- **Smart Environment** that includes factors and indicators such as the attractivity of natural conditions (green areas, climate etc.), pollution, environmental protection policies and sustainable natural resources management;
- **Smart Living** that comprises indicators linked to the quality of life as cultural facilities and touristic attractivity, health conditions, individual safety, housing quality, education facilities and social cohesion.

Despite the fact that the researchers tried to employ as much as possible data coming from regional and local databases, many indicators were deducted by data contained in national databases because they were available only on that level. The indicators based on regional/local data and on national data are respectively 48 and 26, which correspond to the 65% and 35% of the indicators.

The developers tried to employ the most current data as possible, trying to balance the recentness of data with their availability and thus data ranges from 2001 to 2007, which is the year of the publication of the ranking.

Table 27 shows the TU Wien's complete list of the indicators of smartness, their relation with the factors and the main characteristics, the year to which they refer and to the spatial level of the database employed, be it local, regional or national. The indicators related to the provision of smart services are highlighted in yellow.

Main Characteristic	Factor	Indicator	Year	Spatial Level
Smart Economy	Innovative spirit	R&D expenditure in % of GDP	2003	regional
		Employment rate in knowledge-intensive sectors	2004	regional
		Patent applications per inhabitant	2003	regional
	Entrepreneurship	Self-employment rate	2001	local
		New businesses registered	2001	local
	Economic image & trademarks	Importance as decision-making centre (HQ etc.)	2007	regional
	Productivity	GDP per employed person	2001	local
	Flexibility of labour market	Unemployment rate	2005	regional
		Proportion in part-time employment	2001	local
	International embeddedness	Companies with HQ in the city quoted on national stock market	2001	local
		Air transport of passengers	2003	regional
		Air transport of freight	2003	regional
Smart People	Level of qualification	Importance as knowledge centre (top research centres, top universities etc.)	2007	regional
		Population qualified at levels 5-6 ISCED	2001	local
		Foreign language skills	2005	national
	Affinity to lifelong learning	Book loans per resident	2001	local
		Participation in life-long-learning in %	2005	regional
		Participation in language courses	2005	national
	Social and ethnic plurality	Share of foreigners	2001	local
		Share of nationals born abroad	2001	local
	Flexibility	Perception of getting a new job	2006	national
	Creativity	Share of people working in creative industries	2002	national
	Cosmopolitanism/ Open-mindedness	Voters turnout at European elections	2001	local
		Immigration-friendly environment (attitude towards immigration)	2006	national
		Knowledge about the EU	2006	national
	Participation in public life	Voters turnout at city elections	2001	local
		Participation in voluntary work	2004	national

Main Characteristic	Factor	Indicator	Year	Spatial Level
Smart Governance	Participation in decision-making	City representatives per resident	2001	local
		Political activity of inhabitants	2004	national
		Importance of politics for inhabitants	2006	national
		Share of female city representatives	2001	local
	Public and social services	Expenditure of the municipal per resident in PPS	2001	local
		Share of children in day care	2001	local
		Satisfaction with quality of schools	2005	national
	Transparent governance	Satisfaction with transparency of bureaucracy	2005	national
		Satisfaction with fight against corruption	2005	national
Smart Mobility	Local accessibility	Public transport network per inhabitant	2001	local
		Satisfaction with access to public transport	2004	national
		Satisfaction with quality of public transport	2004	national
	(Inter-)national accessibility	International accessibility	2001	regional
	Availability of ICT-infrastructure	Computers in households	2006	national
		Broadband internet access in households	2006	national
	Sustainable, innovative and safe transport systems	Green mobility share (non-motorized individual traffic)	2001	local
		Traffic safety	2001	local
		Use of economical cars	2006	national
Smart Environment	Attractivity of natural conditions	Sunshine hours	2001	local
		Green space share	2001	local
	Pollution	Summer smog (Ozon)	2001	local
		Particulate matter	2001	local
		Fatal chronic lower respiratory diseases per inhabitant	2004	regional
	Environmental protection	Individual efforts on protecting nature	2004	national
		Opinion on nature protection	2006	national
	Sustainable resource management	Efficient use of water (use per GDP)	2001	local
		Efficient use of electricity (use per GDP)	2001	local

Main Characteristic	Factor	Indicator	Year	Spatial Level
Smart Living	Cultural facilities	Cinema attendance per inhabitant	2001	local
		Museums visits per inhabitant	2001	local
		Theatre attendance per inhabitant	2001	local
	Health conditions	Life expectancy	2001	local
		Hospital beds per inhabitant	2001	local
		Doctors per inhabitant	2001	local
		Satisfaction with quality of health system	2004	national
	Individual safety	Crime rate	2001	local
		Death rate by assault	2001-03	regional
		Satisfaction with personal safety	2004	national
	Housing quality	Share of housing fulfilling minimal standards	2001	local
		Average living area per inhabitant	2001	local
		Satisfaction with personal housing situation	2004	national
	Education facilities	Students per inhabitant	2001	local
		Satisfaction with access to educational system	2004	national
		Satisfaction with quality of educational system	2004	national
	Touristic attractivity	Importance as tourist location (overnights, sights)	2007	regional
		Overnights per year per resident	2001	local
	Social cohesion	Perception on personal risk of poverty	2006	national
		Poverty rate	2005	national

Table 27: *Indicators of smartness, factors and main characteristics of the Ranking Of European Medium-Sized Smart Cities (Giffinger et al., 2007).*

By analyzing the list of the indicators employed in the ranking, it can be inferred that only one indicator is related to the provision of smart services. The methodology employed to obtain the indicator as well as the sources of the data are not reported in the report of the ranking, as it is shown in Table 28, which shows the methodology and the source of the data of the indicator related to the provision of smart services employed by the TU Wien ranking.

Indicator	Methodology / Description	Source
Broadband internet access in households	Not Available	Not Available

Table 28: *Smart service-related indicator of Ranking Of European Medium-Sized Smart Cities (Giffinger et al., 2007).*

IESE City In Motion Index (CIMI)

As aforementioned, while developing the CIMI, the researchers focused on the creation of a new and more reliable, complete and objective system of indicators, in order to provide a useful decision making tool to local authorities and governments.

While taking into account aspects such as the promotion of the entrepreneurial spirit, the development of the global city and the innovation, the researchers elaborated a system of 83 indicators of smartness, which are related the key dimensions and reflect both objective and subjective data, providing a global view of each city.

Researchers determined nine key dimensions: human capital, social cohesion, economy, governance, the environment, mobility and transportation, urban planning, international outreach and, finally, technology. These dimensions have been identified by taking into account different aspects of a smart city such as sustainability and quality of life of the inhabitants both in the present and in the future. More specifically the evaluations of the dimensions have been built through the weighted aggregation of the indicators that are related to each dimension.

Table 29 shows the CIMI's list of indicators of smartness, their description, the sources from which data have been taken and their relation with the key dimensions. The indicators related to the provision of smart services are highlighted in yellow.

Dimension	Indicator	Description / Unit of Measurement	NO.	Source
Human capital	Higher education	Proportion of population with secondary and higher education.	1	Euromonitor
	Business schools	Number of business schools (top 100).	2	Financial Times
	Movement of students	International movement of higher-level students. Number of students.	3	UNESCO
	Universities	Number of universities in the city that are in the top 500.	4	QS Top Universities
	Museums and art galleries	Number of museums and art galleries per city.	5	OpenStreetMap
	Schools	Number of public or private schools per city.	6	OpenStreetMap
	Theaters	Number of theaters per city.	7	OpenStreetMap
	Expenditure on leisure and recreation	Expenditure on leisure and recreation per capita.	8	Euromonitor
	Expenditure on leisure and recreation	Expenditure on leisure and recreation. Expressed in millions of U.S. dollars at 2014 prices.	9	Euromonitor

Dimension	Indicator	Description / Unit of Measurement	NO.	Source
Social cohesion	Ratio of deaths	Ratio of death per 100,000 inhabitants.	10	Euromonitor
	Crime rate	Crime rate.	11	Numbeo
	Health	Health index.	12	Numbeo
	Unemployment	Unemployment rate (number of unemployed out of the workforce).	13	Euromonitor
	Gini index	The Gini index varies from 0 to 100, with 0 being a situation of perfect equality and 100 that of perfect inequality.	14	Euromonitor
	Price of property	Price of property as percentage of income.	15	Numbeo
	Ratio of female workers.	Ratio of female workers in the public administration.	16	International Labour Organization
	Global Peace Index	The Global Peace Index is an indicator that measures the peacefulness and the absence of violence in a country or region. The bottom-ranking positions correspond to countries with a high level of violence.	17	Institute for Economics and Peace
	Hospitals	Number of public and private hospitals and health centers per city.	18	OpenStreetMap
	Happiness index	Happiness index of a country. The highest values on the index indicate countries that have a higher degree of overall happiness.	19	World happiness index
	Global Slavery Index	Ranking that considers the proportion of people in a situation of slavery in the country. The countries occupying the top positions in the ranking are those with the highest proportion of the population in a situation of slavery.	20	Walk Free Foundation
	Government response to situations of slavery	This variable measures how the government deals with situations of slavery in the country. The top positions in the ranking indicate countries that have a more effective and comprehensive response to slavery.	21	Walk Free Foundation
	Terrorism	Number of terrorist acts of vandalism by city in the previous three years.	22	Global Terrorism Database, University of Maryland
Economy	Productivity	Labor productivity calculated as GDP per working population (in thousands).	23	Euromonitor
	Time required to start a business	Number of calendar days needed so a business can operate legally.	24	World Bank
	Ease of starting a business	Ease of starting a business. Top positions in the ranking indicate a more favorable regulatory environment for creating and operating a local company.	25	World Bank
	Headquarters	Number of headquarters of publicly traded companies.	26	Globalization and World Cities (GaWC)
	Motivation for early-stage entrepreneurial activity	Percentage of people involved in total entrepreneurial activity (TEA) who are motivated by an opportunity for improvement, divided by the percentage of TEA motivated by need. Total entrepreneurial activity (TEA): new entrepreneurs or owners/managers of a new business.	27	Global Entrepreneurship Monitor
	Growth forecast	Forecast of annual GDP growth rate.	28	Euromonitor
	GDP	Gross domestic product in millions of U.S. dollars at 2014 prices.	29	Euromonitor
	GDP per capita	Gross domestic product per capita at 2014 prices.	30	Euromonitor

Dimension	Indicator	Description / Unit of Measurement	NO.	Source
Governance	Reserves	Total reserves in millions of current U.S. dollars. Estimate at city level according to the population.	31	World Bank
	Reserves per capita	Reserves per capita in millions of current U.S. dollars.	32	World Bank
	Embassies	Number of embassies per city.	33	OpenStreetMap
	ISO 37120 certification	This establishes whether or not the city has ISO 37120 certification. Certified cities are committed to improving their services and quality of life. Variable coded from 0 to 6. Cities that have been certified for the longest time have the highest value. The value 0 is for cities without certification.	34	World Council on City Data (WCCD)
	Research centers	Number of research and technology centers per city.	35	OpenStreetMap
	Strength of legal rights	The strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate access to loans. The values go from 0 = low to 12 = high, where the highest ratings indicate that the laws are better designed to expand access to credit.	36	World Bank
	Corruption perceptions	Corruption perceptions index. Countries with values close to 0 are perceived as very corrupt and those with an index close to 100 are perceived as very transparent.	37	Transparency International
	Open data platform	This describes whether the city has an open data system.	38	CTIC Foundation and Open World Bank
	E-Government Development Index	The E-Government Development Index (EGDI) reflects how a country is using information technology to promote access and inclusion for its people.	39	United Nations
	Democracy	Ranking where the countries in the highest positions are those considered more democratic.	40	The Economist
	Government buildings	Number of government buildings and premises in the city.	41	OpenStreetMap
The environment	CO_2 emissions	Carbon dioxide emissions that come from the burning of fossil fuels and the manufacture of cement. Measured in kilotons (kt).	42	World Bank
	CO_2 emission index	CO_2 emission index.	43	Numbeo
	Methane emissions	Methane emissions that arise from human activities such as agriculture and the industrial production of methane. Measured in kt of CO_2 equivalent.	44	World Bank
	Access to the water supply	Percentage of the population with reasonable access to an appropriate quantity of water resulting from an improvement in the water supply.	45	World Bank
	PM2.5	PM2.5 measures the number of particles in the air whose diameter is less than 2.5 μm. Annual mean.	46	World Health Organization
	PM10	PM10 measures the number of particles in the air whose diameter is less than 10 μm. Annual mean.	47	World Health Organization
	Pollution	Pollution index.	48	Numbeo
	Environmental performance index	This measures environmental health and ecosystem vitality. Scale from 1 (poor) to 100 (good).	49	Yale University
	Renewable water resources	Total renewable water sources per capita.	50	FAO
	Future climate	Percentage of summer temperature increase in the city forecast for 2100 if carbon pollution continues to increase.	51	Climate Central
	Solid waste	Average amount of municipal solid waste (garbage) generated annually per person (kg/yr).	52	Waste Management for Everyone

Dimension	Indicator	Description / Unit of Measurement	NO.	Source
Mobility and transportation	Traffic index	The traffic index is estimated by considering the time spent in traffic and the dissatisfaction this generates. It also includes estimates of CO2 consumption and the other inefficiencies of the traffic system.	53	Numbeo
	Inefficiency index	The inefficiency index is an estimate of the inefficiencies in traffic. High values represent high rates of inefficiency in driving, such as long journey times.	54	Numbeo
	Index of time spent commuting to work	Index of time based on how many minutes it takes to commute to work.	55	Numbeo
	Bike sharing	The bicycle-sharing system shows the automated services for the public use of shared bicycles that provide transport from one location to another within a city. The indicator varies between 0 and 8 according to how developed the system is.	56	Bike-Sharing World Map
	Metro length	Length of the metro system per city.	57	Metrobits.org
	Metro stations	Number of metro stations per city.	58	Metrobits.org
	Flights	Number of arrival flights (air routes) in a city.	59	OpenFlights
	Gas stations	Number of gas stations per city.	60	OpenStreetMap
	High-speed train	Binary variable that shows whether the city has a high-speed train or not.	61	OpenRailwayMap
Urban planning	Bicycles for rent	Number of bike-rental or bike-sharing points, based on docking stations where they can be picked up or dropped off.	62	OpenStreetMap
	Percentage of the population with access to sanitation facilities	Percentage of the population with at least sufficient access to facilities for the disposal of excreta that can efficiently avoid the contact of humans, animals and insects with excreta.	63	World Bank
	Number of people per household	Number of people per household. Occupancy by household is measured compared to the average. This makes it possible to estimate if a city has overoccupied or underoccupied households.	64	Euromonitor
	High-rise buildings	Percentage of buildings that are considered high-rises. A high-rise is a building of at least 12 stories or 35 meters (115 feet) high.	65	Skyscraper Source Media
	Buildings	The buildings variable is the number of completed buildings in the city. This includes structures such as high-rises, towers and smaller buildings but excludes other diverse structures and buildings in different states of completion (in construction, planned, etc.).	66	Skyscraper Source Media
International outreach	McDonald's	Number of McDonald's restaurants per city.	67	OpenStreetMap
	Airports	Number of points where flight operations take place within a 40 km radius from the latitude and longitude defining the center of the city. It includes airports, aerodromes, airfields, and landing strips whether international, private, military or otherwise. Also included are the buildings used for processing passengers and cargo (terminals).	68	OpenStreetMap
	Number of passengers per airport	Number of passengers per airport in thousands.	69	Euromonitor
	Sightsmap	Ranking of cities according to the number of photos taken in the city and uploaded to Panoramio (community for sharing photographs online). The top	70	Sightsmap

		positions correspond to the cities with the most photographs.		
	Number of conferences and meetings	Number of international conferences and meetings that take place in a city.	71	International Congress and Convention Association
	Hotels	Number of hotels per capita.	72	OpenStreetMap
Technology	Twitter	Registered Twitter users in the city. This is part of the "social media" variable.	73	Tweet Map
	LinkedIn	Number of registered users in the city. This is part of the "social media" variable.	74	LinkedIn
	Facebook	Number of people who are currently registered in the city. Facebook is part of the "social media" variable.	75	Facebook
	Mobile phones	Number of mobile phones in the city. Taken at the country level.	76	International Telecommunication Union
	Wi-Fi hot spot	Number of wireless access points globally. These represent the options there are in the city for connecting to the Internet.	77	Wifi map app
	Apple Store	Number of Apple Stores per city.	78	OpenStreetMap
	Innovation index	The city's innovation index. Valuation of 0 = no innovation to 60 = a lot of innovation.	79	Innovation Cities Program
	Landline subscriptions	Number of landline subscriptions per 100 inhabitants.	80	International Telecommunication Union
	Broadband subscriptions	Broadband subscriptions per 100 inhabitants.	81	International Telecommunication Union
	Internet	Percentage of households with access to the Internet.	82	Euromonitor
	Mobile telephony	Percentage of households with mobile phones in the city.	83	Euromonitor

Table 29: *Indicators, description and sources of data of the IESE City In Motion Index (IESE, 2018).*

As can be deduced from the list of indicators used in IESE City In Motion Index, seven indicators are related to the provision of smart services.

Table 30 illustrates the methodology and the source of the data of the indicators of the IESE City In Motion Index related to the provision of innovative smart services.

Indicator	Methodology / Description	Source
Open data platform	Presence of an open data system in the city	CTIC Foundation and Open World Bank
E-Government Development Index (EGDI)	It is a composite indicator related to the provision of online services at a national level	United Nations
Bike sharing	The indicator varies between 0 and 8 according to how developed the system is	Bike-Sharing World Map

Bicycles for rent	Number of bike-rental or bike-sharing points, based on docking stations where they can be picked up or dropped off.	OpenStreetMap
Wi-Fi hot spot	Number of wireless access points globally in the city	Wifi map app
Broadband subscriptions	Broadband subscriptions per 100 inhabitants	International Telecommunication Union
Internet	Percentage of households with access to the Internet	Euromonitor

Table 30: *Smart service-related indicators of the IESE City In Motion Index (IESE, 2018).*

2017 Smart City Index

As already explained in the previous paragraph, seven main categories exists in the 2017 Smart City Index: transport and mobility, sustainability, governance, innovation economy, digitalization, living standard and expert perception. The main categories are related to 19 factors which, in turn, are made up by 39 indicators of smartness.

Table 31 shows the 2017 Smart City index's list of indicators of smartness, the sources from which data have been extracted and their relation with the factors and the main categories. The indicators related to the provision of smart services are highlighted in yellow.

Dimension/ Main Category	Factor	Indicator	Source
Transport And Mobility	Smart Parking	Percentage of people owning cars (city)	local census reports, Eurostat NUTS 2 statistical level data
		Number of parking spaces in city center per klm2	
		Smartphone penetration	local reports, online databases
		Availability of parking apps and usage penetration	
	Car Sharing Services	Estimation of the car sharing industry fleet (number of cars) in the city with respect to the city's population	reports, official sites of car2Go, GoGet, Zipcar, DriveNow, Communauto, Car4away, Autonapůl, LetsGo, GreenMobility, Autolib', GoCar, Enjoy, XXImo, Bluemove, Sunfleet, Mobility Carsharing and Flinkster
		Population data	Google
	Traffic	Levels of congestion	TomTom Traffic index, INRIX traffic scorecard (adjusted to TomTom), Google traffic (adjusted to TomTom)
	Public Transport	Public transport satisfaction percentage	local reports, European Commission report

Dimension/ Main Category	Factor	Indicator	Source
Sustainability	Clean Energy	Percentage of electricity production from renewable sources	International Energy Statistics report
	Smart Building	Research centers: Investment to research and development (percentage of GDP)	Global Innovation Index 2017
		Efficiency of buildings: GDP per unit of energy use	Global Innovation Index 2017
	Waste Disposal	Percentage of waste landfilled	local reports, United Nations
	Environment Protection	Green House Gases emission per capita	United Nations
		CO2 Emissions per capita	United Nations
		Adjusted to population	Population data from Google
Governance	Citizen Participation	Election turnout for parliament, percentage	International Institute for Democracy and Electoral Assistance. Where no parliament exists, local elections participation rate was used
	Digitalization of Government	Digital Infrastructure Rank	Digital City Index
		Traffic of local government sites as a percentage of the population	
	Urban Planning	Rank according to percentage of green public areas in the city	Data from city records and satellite data (Google)
	Education	PCs per 1000 population	Online databases and local reports
		Information technologies development index (Measuring the Information Society Report)	International Telecommunications Union
		Number of universities the country has in the top university list, country level	World University Rankings 2016
		Number of universities in the top 10 list, city level	World University Rankings 2016
		Number of students in top 3 universities from the list, city level	World University Rankings 2016
		Adjusted to city population, country population	Google
Innovation Economy	Business Ecosystem	Business Ecosystem	Global Innovation Index
		Number of startups	Angel.co
		Adjusted to population	Google
Digitalization	4G LTE	Mbs, Speed Test Global Index (mobile)	Online Speed Test
	Internet Speed	Download Mbs, Speed Test Global Index (fixed broadband)	Online Speed, Test Global Index
		Download Mbs	Ookla

		Download Mbs	Digital City Index
	Wi-Fi Hotspots	Free Wi-Fi hotspots	Online Wi-Fi databases
		Adjusted to the city area	Google
	Smartphone Penetration	Smartphone penetration (country)	Local reports, online databases
Living Standard	Living Standard	Average sum spent on (Fast food, Restaurant, Clothes, Rent, Transportation)	Expanistan
		Average Net Salary	Average salary survey data
		Adjusted to the GDP per capita levels	World Bank Data
Expert Perception	Expert Perception	20,000 technology and urban planning journalists were asked to rate how smart each city was	Poll, only on top 100 cities

***Table 31:** Indicators, dimensions, factors and sources of data of the 2017 Smart City index (EasyPark Group website)*

By analyzing the list of the indicators employed in the 2017 Smart City Index, it can be seen that eight indicators are related to the provision of smart services.

Table 32 illustrates the methodology and the sources of the data of the indicators employed in the 2017 Smart City Index and related to the provision of innovative ICT-based services.

Indicator	Methodology / Description	Source
Availability of parking apps and usage penetration	Number of parking apps and their users	Not available
Estimation of the car sharing industry fleet (number of cars) in the city with respect to the city's population	Number of cars employed for car sharing with respect to the city's population	Reports, official sites of car2Go, GoGet, Zipcar, DriveNow, Communauto, Car4away, Autonapůl, LetsGo, GreenMobility, Autolib', GoCar, Enjoy, XXImo, Bluemove, Sunfleet, Mobility Carsharing and Flinkster
Mbs, Speed Test Global Index (mobile 4G LTE))	Online test that measures the speed connection through test servers	Online Speed Test by Ookla
Download Mbs, Speed Test Global Index (fixed broadband)	Index that considers the monthly average speed of a Country (national level)	Online Speed Test, Test Global Index by Ookla
Download Mbs (fixed broadband, source Ookal)	Online test that measures the speed connection through test servers	Ookla
Download Mbs (fixed broadband, source Digital City Index)	Average download speed in a city taken from the composite Indicator Digital City Index	Digital City Index which employs Ookla
Free Wi-Fi hotspots	Number of Wifi Hotspots in a city	Online Wi-Fi databases
Free Wi-Fi hotspots adjusted to the city area	Not available	Google

***Table 32:** Smart service-related indicator of the 2017 Smart City Index (EasyPark Group website)*

It is interesting to notice that it seems that the "Download Mbs (fixed broadband, source Ookal)" and the "Download Mbs (fixed broadband, source Digital City Index)" are **redundant** because they measure the same data according to the same source. In fact, the first one measures the download speed of the broadband according to the online tests provided by Ookla. The second one reports the broadband download speed according to the Digital City Index, which in turn relies on the online tests provided by Ookla.

ICity rate 2017

The 106 provincial capitals, which constitute the sample of cities analized by the developers of the ranking, had been evaluated according to the performances achieved in 113 indicators, or sub dimensions, which had been grouped under 15 main dimensions.

The scores related to the indicators had been elaborated and aggregated according to the main dimension to which the indicators belongs so that to produce a unique score for each dimesion. The scores of the main dimesion had been later aggregated to build a the total score of the ranking. The main dimensions are governance and participation, legality and safety, research and innovation, digital transformation and transparency, culture and tourism, employment, economic growth, sustainable mobility, poverty, education, air and water quality, energy, green urban areas, soil and land, and finally waste.

Table 33 shows the list of ICity rate 2017 indicators of smartness, the sources from which data have been extracted and their relation with the main categories. The indicators related to the provision of smart services are highlighted in yellow.

Dimension	Indicator	Sources
Poverty	Economic Pain	MEF - Dipartimento delle Finanze
	Population At Risk Of Poverty	Istat
	Housing Deprivation	Italian Agency of Revenue
	Evictions	Ministry of the Interior
	Healthcare Migration	Istat
	Daycare Availability	Istat
	Care For The Elderly	Istat
	Healthcare Professional	Istat
	Refugee Reception	SPRAR
Education	Early Leavers	Istat
	Tertiary Education	Istat
	Access To Education	Istat

Dimension	Indicator	Sources
Air Quality And Water Efficiency	Dispersion Of Water	Ispra
	Wastewater Treatment	Ispra
	Water Purification	Legambiente
	PM10	Ispra
	PM2,5	Ispra
	NO2	Ispra
Energy	Renewable Energy Produced By The Municipalities	Istat
	Consumption	Istat
	Quality Of The Electrical Service	Istat
	Covenant And Network For Sustainability	Piano di Azione per l'Energia Sostenibile (PAES)
Economic Growth	Productivity	Unioncamere, Istituto Guglielmo Tagliacarne
	Disposable Income	Unioncamere, Istituto Guglielmo Tagliacarne
	Entrepreneurship	Unioncamere, Istituto Guglielmo Tagliacarne
	Availability Of Credit	Bank Of Italy
	Manageriality	Istat - ASIA
	Value Of Exportations per capita	Istat - Ice
	Overnight Stays For Work Purposes	Istat, Bank Of Italy
	Knowledge-Intensive Companies	Unioncamere, Istituto Guglielmo Tagliacarne
	FABLAB	MAKERS ITALIA, fabfoundation
	Innovative Start Ups	Unioncamere, Istituto Guglielmo Tagliacarne
	Co-working	FPA
	Corporate Credit	Unioncamere, Istituto Guglielmo Tagliacarne
Employment	Involvement In The Labour Market	Istat
	Fluidity Of The Labour Market	Istat
	Gender Equity In Employment	Istat
	Employment Rate	Istat
	Unemployment Rate	Istat
	Qualification Of The Workforce	Istat
	Illegal Work	Istat
	Work Accidents	Inail

Dimension	Indicator	Sources
Culture And Tourism	Shows Attendance	SIAE, Istat
	Attractiveness	Tripadvisor
	Employment In The Tourist Industry	Unioncamere, Istituto Guglielmo Tagliacarne, Fondazione Symbola
	Exportations	Unioncamere, Istituto Guglielmo Tagliacarne, Fondazione Symbola
	Cultural Heritage	Ministry of Cultural Heritage and Activities and Tourism
	Ecolabel	Ispra
	Tourism Rate	Istat
	Historical Companies	Istituto Guglielmo Tagliacarne
	Tourism Outside Summertime	Istat
	Touristic Entrepreneurship	Unioncamere, Istituto Guglielmo Tagliacarne, Fondazione Symbola
	Tourism Expenditure	Istat
Research And Innovation	Manufacturing Innovation	Istat
	Number Of Patents	Istituto Guglielmo Tagliacarne
	E-Commerce	Istat
	Attractiveness Due To Financing	APRE
Digital Transformation	Home Banking Diffusion	Bank Of Italy, Istat
	Broadband 30MBps	Infratel
	Broadband 100MBps	Infratel
	Connectivity In Residential Areas	Sostariffe.it
	Ultra-Wideband Diffusion	Istat, AGCOM
	Digital Growth	Ministry of the Interior
	Open Data	FPA
	Public Authorities Social	FPA
	Online Services	Istat
	Public Wi-Fi	Istat
Sustainable Mobility	Mobility Planning And 30 km/h Zones	Istat, Ispra, Osservatorio Pums
	Traffic Limitations	Istat
	Pedestrianization Policies	Istat
	Interchange	Istat
	Bicycle Paths	Istat
	Low-Emission Vehicles	ACI, Istat
	Traditional Fuels Vehicles	ACI
	Electric Mobility	Enel Drive, A2A, Hera
	Bike Sharing	Osservatorio Sharing Mobility
	Carsharing	Osservatorio Sharing Mobility
	Public Transport Supply	Istat
	Importance Of Public Transport	Istat
	Accidents	Aci – Istat
	Pedestrian Areas	Istat

Dimension	Indicator	Sources
Waste	Separate Collection	Ispra
	Waste Production	Ispra
	Waste Disposal	Istat
Green Urban Areas	Green Areas Importance	Istat
	Green Areas Availability	Istat, Ispra
	Green Areas Planning	Istat, Ispra
Soil And Land	Soil Consumption Per Capita	Ispra, ARPA, APPA
	Soil Already Consumed	Ispra
	Risk Mitigation	Protezione Civile
Legality And Safety	Urban Petty Crime	Istat
	Murders	Ministry of the Interior, Istat
	Illegality Among Business Owners	Unioncamere, Istituto Guglielmo Tagliacarne
	Money Laundering	Unioncamere, Istituto Guglielmo Tagliacarne
	Illegality Related To The Concrete-Cycle	Legambiente
	Illegality Related To Waste Management	Legambiente
	Courts Efficiency	Ministry of the Interior
	Social Utility Of Confiscated Properties	ANBSC
	Municipalities Under Temporary Receivership	Avviso Pubblico
	Organized Crime And Mafia	Unioncamere, Istituto Guglielmo Tagliacarne
	Threats To Local Authorities	Avviso Pubblico
Governance And Participation	Share Capital Of Cooperatives	Istat
	Social Participation	Istat, 2011 Census
	Electoral Participation	Ministry of the Interior
	Level Of Trust In The Institutions	Istat
	Economic Stability	Openpolis
	Management Skills	Openpolis
	Innovative Urban Planning And Development	FPA
	Urban Attractiveness	Istat
	Participation In The Administration	FPA
	Public Authority Green	Istat
	Social Innovation	FPA
	Gender Equity Among Mayors	Ministry of the Interior

Table 33: *Indicators, dimensions and sources of data of ICity Rate 2017 (FORUM PA, 2017).*

As can be deduced from the list of indicators used in ICity rate 2017, 14 indicators are related to the provision of smart services.

Table 34 illustrates the methodology and the source of the data of the indicators employed in this ranking related to the provision of innovative smart services.

Indicator	Methodology / Description	Source
Co-working	Coworking services percentage in a city of the total in Italy.	Data collected directly by Forum PA
E-Commerce	Companies that sold or bought products online during the previous year	Istat
Home Banking Diffusion	Number of clients of home and corporate banking services	Forum PA calculations on data coming from Bank of Italy and Istat
Broadband 30MBps	Percentage of dwellings in a city reached by a 30MBps connection	Infratel
Broadband 100MBps	Percentage of dwellings in a city reached by a 30MBps connection	Infratel
Connectivity In Residential Areas	Average download speed (Mbps) for ADSL users in a city	Sostariffe.it
Ultra-Wideband Diffusion	Number of subscriptions to ultrabroadband as a percentage of the population of a city	Istat calculations on data coming from AGCOM
Digital Growth	Composite indicator that takes into account the number of services that accept SPID and CIE and the number of administrations that adopt Pago PA and Fattura PA	Forum PA calculations on data coming from AGID and Ministry of the Interior
Open Data	Indicator based on the number of dataset available, the presence of a dedicated web page, feedback/demand analysis tools, presence of an application	Data collected directly by Forum PA
Online Services	Good fruition level (3 or 4) of online service as a percentage of the total number of online services	Istat
Public Wi-Fi	Number of free WiFi access point per 100.000 inhabitants	Istat
Electric Mobility	Number of electric vehicles charging stations per square Km	Forum PA calculations on data coming from Enel Drive, A2A, Hera and other operators
Bike Sharing	Number of bicycles, employed in bike sharing services, available per 1000 inhabitants	Forum PA calculations on data coming from Osservatorio Sharing Mobility
Carsharing	Number of vehicles, employed in car sharing services, available per 1000 inhabitants	Forum PA calculations on data coming from Osservatorio Sharing Mobility

Table 34: *Smart service-related indicators of ICity Rate 2017 (FORUM PA, 2017).*

2.4 Comparison Analysis Of Sets Of Indicators Of The Different Ranking Systems With Respect To Innovative ICT-Based Services

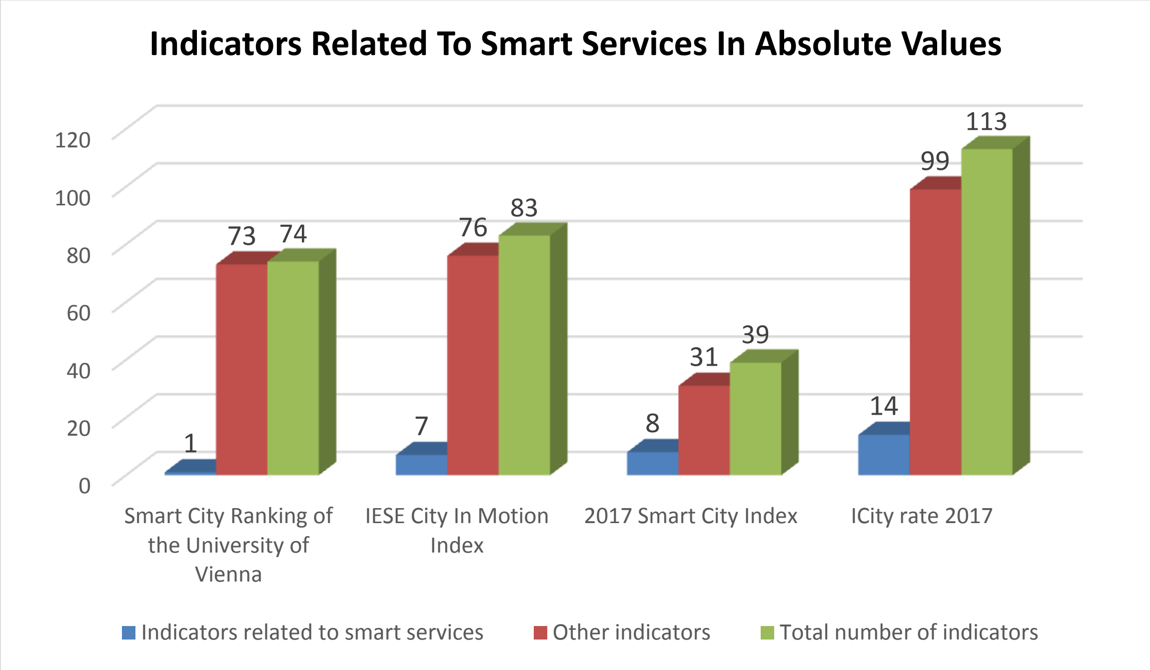
This paragraph is dedicated to the comparison of the four rankings presented and analyzed in the previous sections of this chapter. The aim of the comparison is to individuate and choose the best and most comlplete ranking with respect to the provision of innovative ICT-based services in the smart city context.

Table 35 summarises all the indicators that measures the offer of smart innovative services in a smart city which are employed in each of the previously described rankings.

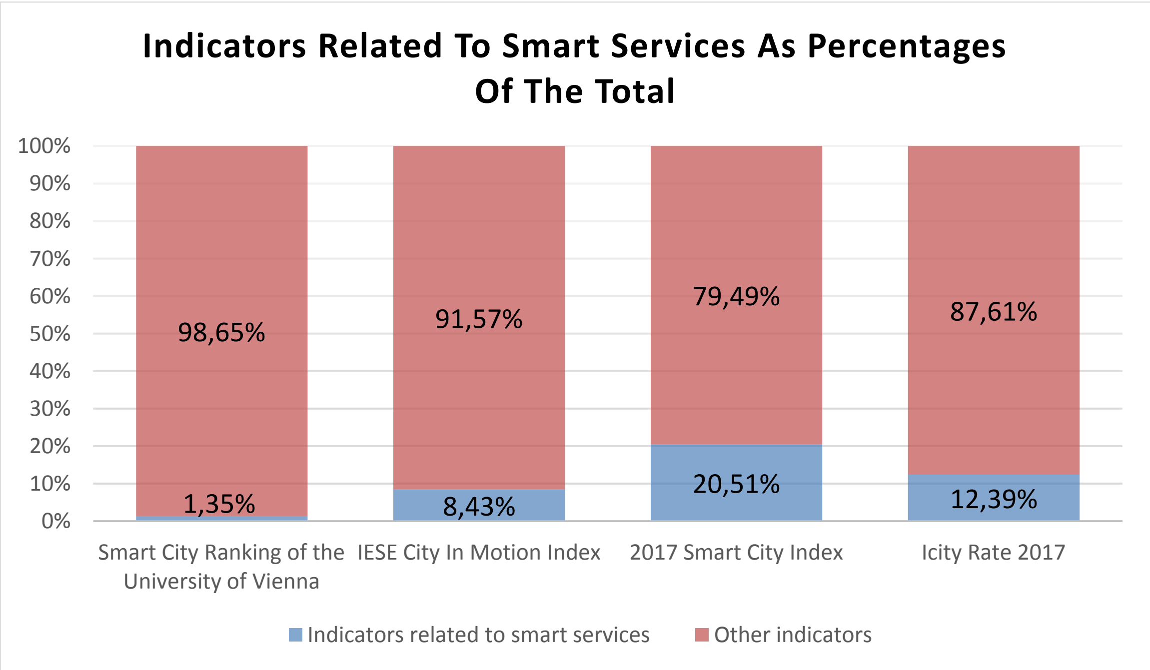
Vienna University Ranking	CIMI Ranking	2017 Smart City Ranking	ICity rate 2017
Broadband internet access in households	Open data platform	Availability of parking apps and usage penetration	Co-working
	E-Government Development Index	Estimation of the car sharing industry fleet (number of cars) in the city with respect to the city's population	E-Commerce
	Bike sharing	Mbs, Speed Test Global Index (mobile 4G LTE)	Home Banking Diffusion
	Bicycles for rent	Download Mbs, Speed Test Global Index (fixed broadband)	Broadband 30MBps
	Wi-Fi hot spot	Download Mbs (fixed broadband,source Ookal)	Broadband 100MBps
	Broadband subscriptions	Download Mbs (fixed broadband, source Digital City Index)	Connectivity In Residential Areas
	Internet	Free Wi-Fi hotspots	Ultra-Wideband Diffusion
		Free Wi-Fi hotspots adjusted to the city area	Digital Growth
			Open Data
			Online Services
			Public Wi-Fi
			Electric Mobility
			Bike Sharing
			Carsharing

Table 35: *Comparison between the four rankings examined with respect to thesmart service-related indicators. Sources of information: Giffinger et al., 2007; IESE, 2018; EasyPark Group website;FORUM PA, 2017.*

The two following graphs enable the reader to understand the relative importance and the significance, in each ranking, of the indicators related to smart services with respect to the other indicators. Graph 1 shows the relative importance of the indicators related to the smart services with respect to the number of the other indicators and to the total in absolute values. Graph 2 instead shows the relative importance of the indicators related to the smart services in percentage terms.



Graph 1: *Indicators Related To Smart Services In Absolute Values. Sources of information: Giffinger et al., 2007; IESE, 2018; EasyPark Group website; FORUM PA, 2017.*



Graph 2: *Indicators Related To Smart Services As Percentages Of The Total. Sources of information: Giffinger et al., 2007; IESE, 2018; EasyPark Group website; FORUM PA, 2017.*

From the previous graphs it seems that the 2017 Smart City Index is the ranking that takes more into account smart service indicators, since they represent the 20,51% of the indicators, followed by ICity Rate 2017 (12,39). However, in absolute terms, ICity Rate 2017 is the ranking that includes the highest number of smart service indicators (14), almost twice the number of 2017 Smart City Index (8).

On the contrary both the Smart City Ranking of the University of Vienna and the IESE City In Motion Index are characterized by the presence of a low number of smart service indicators and by low relative importance of the latters. For this reasons, they will no longer be taken into consideration.

Thus, comparing the 2017 Smart City Index and the ICity Rate 2017 on the basis of the information provided in the previous paragraph, the following observations have been made:

- the methodology used to obtain the indicators has been better defined in ICity Rate 2017;
- the methodology employed in the 2017 Smart City Index is not always clear and sometimes not available. In addition, it appears that two indicators are redundant since they report the same information based on the same source;
- the sources of the data employed by the indicators have been more precisely reported in ICity Rate 2017 and they are sometimes directly collected by Forum PA, thus being firsthand;
- the sources of the data used in the indicators of 2017 Smart City Index are sometimes too general. An example is the source “Google” for the indicator “Free Wi-Fi hotspots adjusted to the city area”;
- the indicators of ICity Rate 2017 take into account different service categories, as it will be shown in the next chapers of the dissertation;
- the indicators of 2017 Smart City Index concern only 2 service categories.

On the basis of these considerations, **ICity Rate 2017** appears to be the best ranking with respect to the purposes of this dissertation and, thus, in the other rankings will no longer be taken into consideration in the following chapters.

Part II

3 Proposal Of Categories Of Innovative ICT-Based Services In The Smart City Context

3.1 Definition Of The Macro-Categories To Which The ICT-Based Services Belong

The aim of this third chapter is to identify and describe the services based on ICT that are provided within the smart city context and the macro categories to which they belong.

Before identifying the innovative services, enabled by ICTs, that are currently offered in the smart cities, it is important to define the categories associated with them. Many service classifications have been produced over the years, each with their own categories, but none of them was specifically designed to help identify smart services and to facilitate the creation of a system of indicators of smartness focused on the provision of innovative ICT-based services.

Thus, this first paragraph is dedicated to suggest new service categories instrumental in the identification of smart services and, above all, in the development of easily manageable indicators of smartness, facilitating their linear independence.

The topic of the smart services presents a high level of complexity and, thus, many classifications have already been developed by researchers over the years. In particular, two academic efforts on the classification of smart services have been taken into account in this dissertation.

The first one is that produced by Alcatel-Lucent Market and Consumer Insight team (Alcatel-Lucent Market and Consumer Insight Team, 2012) and it indicates seven market-driven groups of ICT-related services, both public and private, offered in smart cities.

City Administration: Services to improve efficiency of service delivery and optimize management.

Education: Services to create a more cost-effective, higher quality and accessible education.

Health Care: Services to increase efficiency, efficacy, availability, access, prevention and to reduce costs.

Public Safety: Services to prevent threats and emergencies by improving the response time through real-time control.

Real Estate: Services to improve operating cost-effectiveness, energy efficiency, real estate value and to reduce vacancy rate.

Transportation: Services to avoid traffic congestion by improving the public transportation service as well as service to make the latter safer and more efficient, in order to inspire people to use it.

Utilities: Services to reduce waste of resources (such as energy or water) while managing costs and outages.

The second existing classification reported here is the one elaborated by Leonidas Anthopoulos and Panos Fitsilis (Anthopoulos and Fitsilis, 2013). This classification is, according to the authors, inspired and related with the first one and it presents nine groups of smart services:

E-Government Services: Services concerning the local and national administrative procedures, public complaints, job searches and public procurement. They are related to the City Administration market-driven group and they can be found in the Digital, Smart and Ubiquitous classes.

E-Democracy Services: Services that operate consultation, dialogue, polling and voting about the matters of common interests in the city context. They are related to the City Administration market-driven group and they are available in the Virtual, Digital, Smart and Ubiquitous approaches.

E-Business Services: Services that promote business installation and implement digital marketplaces and tourists guides. They are related to the Real Estate-market driven group and they can be met in the Digital and Smart city classes.

E-Health And Tele-Care Services: Services that provide remote assistance to special typologies of citizens such as the elderly, civilian with disease etc. They are related to the Healthcare market-driven group and they appear in the Digital and Smart city classes.

E-Security Services: Services that promote public safety through amber-alert (child abduction alert system) notifications, school monitoring, natural disaster management etc. They are related to the Public Safety market driven group and they can be found only in the Ubiquitous classes.

Environmental Services: Services that, besides containing public information about recycling, support companies and households in the management of waste, water and energy. In addition they provide State agencies with data for monitoring and decision making on environmental condition such as for microclimate, pollution, noise, traffic etc. They are related to the Utilities market-driven group and they can be met in the Ubiquitous and Eco-City classes.

Intelligent Transportation: Services that enable and increase the quality of life in the city. They also provide tolls for traffic monitoring, measurement and optimization. They are related to the Transportation market-driven group and they are offered by Digital and Smart City approaches.

Communication Services: Services like broadband connectivity, digital TV etc. They are related to the Real Estate market-driven group and they appear in the Broadband, Mobile, Digital, Smart and Ubiquitous classes.

E-Learning And E-Education Services: Services related to the Education market-driven group. They are available in Smart and Digital city approaches.

An additional classification of the ICT-based services in the smart city context can be deduced by the work of the Centre of Regional Science at the TU Wien (Giffinger et al., 2007), which has been already discussed in the second chapter.

In particular, the researchers claims that the six characteristics, on the basis of whose performances the sample of cities had been evaluated, can be seen as the synthesis of the "*several fields of activity which are described in literature in relation to the term Smart City*" and are defined as "*a roof for the further elaboration of smart cities which should incorporate the findings but also allow an inclusion of additional factors*". Thus, this classification of the fields of activity of the smart cities can be consequently extended also to the ICT-based services that exist in the smart city context.

Table 36 summarises the three different ways of categorizing the ICT-based services in a smart city which have been previously described.

Giffinger et al. (2007)	Alcatel-Lucent (2012)	L. Anthopoulos & P. Fitsilis (2013)
Smart Economy	City Administration	E-Government Services
Smart People	Education	E-Democracy Services
Smart Governance	Health Care	E-Business Services
Smart Mobility	Public Safety	E-Health And Tele-Care Services
Smart Environment	Real Estate	E-Security Services
Smart Living	Transportation	Environmental Services
	Utilities	Intelligent Transportation
		Communication Services
		E-Learning e-education services

Table 36: *Comparison between three different categorizations of ICT-based services in a smart city. Sources of information: Giffinger et al., 2007; Alcatel-Lucent, 2012; Anthopoulos and Fitsilis, 2013.*

It is interesting to notice that the differences among these three classification frames relate mainly to the level of details employed by the developers in some dimensions rather than in others, which can be explained by different purposes of the three works. On the contrary, the logic behind these classifications and their general meaning appear to be similar and consistent. The choice of the classification frame is subjective and in this work it has been considered that the three above mentioned classifications represent a collection, a summary of all of the ideas and the activity fields that are necessary for the development of the smart cities and that are behind the very concept of smart city, which has been discussed in the first chapter.

For this reason, this dissertation proposes a hybrid classification, elaborated by taking into account, without any overlaps, the categories included in three categorization systems that have been treated in this section.

Table 37 shows the eight categories of the proposed classification.

Proposed Service Categories
Smart Economy & E-Business Services
Smart People & E-Education Services
Smart Governance Services
City Administration Services
Smart Mobility
Smart Environment Services
Smart Living, Culture & E-Health Services
Smart Communication & ICT-Infrastructure Services

Table 37: *Proposal of new categoriesfor urban smart services.*

3.2 Proposal Of A List Of Innovative Services Enabled By The ICTs In The Smart City Context

The aim of this paragraph is to propose a list of the main "smart" services which exist in the global smart context through the use of ICT.

As already discussed in the first chapter, Urban Facility Management services represent an important, but, of course, not the only field of application of ICT in the smart city context. Many other services which emply ICT have been developed and implement in the smart cities all over the world in recent years.

For this reason, two main typologies of services have been considered in this dissertation: the UFM services and those which are be defined here simply as "Not-UFM Smart Services".

The identification of the services was helped by the services classification proposed in the previous paragraph and by the recognition of the different fields of activities which exist in a smart city. In fact, in order to build a service platform, it could be adopted a methodology proposed by H. Rasila, K. Mikkola and T. Rasila (Rasila et al., 2006), which is based on the identification of the activities performed in a smart city.

According to this methodology, services could be detected by firstly pinpointing the activities performed in the area or in the context under investigation and, then, by subdividing them into sub-activities. The services are, finally, deducted by the sub-activities.

In addition, the list of services was produced by considering real case studies and best practices which have been already implemented all over the world (Ray, 2016; Manville et al., 2014).

Moreover, in addition to everything that has already been said, the identification of the smart UFM services has been performed by taking into consideration the classification of UFM services, included in the Italian standard UNI 11447 that has been already discussed and reported in chapter 1.

The ICT-based services which have been identified are presented in Tables 38, 39, 40, 41, 42, 43, 44 and 45 according to the eight categories of the classification proposed in the previous paragraph.

	Smart Economy & E-Business Services
Not-UFM Smart Services	Smart Food
	E-Commerce
	E-Banking
	Space Sharing: Coworking & Home Sharing

Table 38: *Innovative ICT-based services belonging to the Smart Economy & E-Business category.*

	Smart People & E-Education Services
Not-UFM Smart Services	Smart Services For Citizens Participation And Social Cohesion
	E-Learning And Other E-Education Services

Table 39: *Innovative ICT-based services belonging to the Smart People & E-Education category.*

	Smart Governance Services
UFM Services	Digitalization of the public administration and management of documents, archives, print and similar
	Free open data from the P.A.

Table 40: *Innovative ICT-based services belonging to the Smart Governance category.*

	City Administration Services
UFM Services	Management and maintenance of smart buildings and of their systems
	Management, operation and maintenance of heat station and heating systems
	Management, operation and maintenance of air treatment systems
	Management, operation and maintenance of clean water and sewage systems
	Management, operation and maintenance of electrical and lighting technologies systems
	Management, operation and maintenance of smart grids
	Management, operation and maintenance of the technological security systems
	Management, operation and maintenance of technological control systems
	Management, operation and maintenance of elevators and lifting systems
	Waste collection and disposal management

Table 41: *Innovative ICT-based services belonging to the City Administration category.*

	Smart Mobility Services
Not-UFM Smart Services	Car, Scooter and Bike Sharing & Carpooling
	Autonomous transport
	Journey or trip planning
	Electric Vehicles Charging stations
	Smart Parking
	Smart Public Transport
UFM Services	Maintenance and monitoring of road surface markings, vertical road signs and luminous road signs
	Verification, monitoring and control of the road network
	Maintenance of road surface and quick response for dips
	Operation and maintenance of smart traffic monitoring systems
	Operation and maintenance of smart parking

Table 42: *Innovative ICT-based services belonging to the Smart Mobility category.*

	Smart Environment Services
UFM Services	Air Quality And Pollution Management

Table 43: *Innovative ICT-based services belonging to the Smart Environment category.*

	Smart Living, Culture & E-Health Services
Not-UFM Smart Services	Remote and teleassistance, medicines home delivery and other health services
	Digitalization of museums and historical archive collections and other cultural services

Table 44: *Innovative ICT-based services belonging to the Smart Living, Culture & E-Health category.*

	Smart Communication & ICT-Infrastructure Services
UFM Services	Management, operation and maintenance of broadband and ultrabroadband, phone and data transmission networks
	Free WiFi and cellular mobile communication technologies

Table 45: *Innovative ICT-based services belonging to the Smart Communication & ICT-Infrastructure category.*

The following sections provide the reader with a general description of the categories of ICT-based services that have been previously presented. In particular, they focus on some services which can be considered notable, in terms of importance, widespread or innovation. In many cases, the descriptions of these services have been taken from real case studies and best practices, which have been taken mostly from the same source, Mapping Smart Cities in the EU (Manville et al., 2014), unless otherwise specified.

3.2.1 Smart Economy & E-Business Services

The first category of services that has been presented is the Smart Economy & E-Business that includes several ICT-based services mainly offered by the pivate sector, among which it has been identified:

- *smart food services;*
- *e-commerce services;*
- *e-banking services;*
- *space sharing services (coworking and home sharing).*

Smart food refers to the innovative services that, thanks to dedicated apps, allow customers to order and customize dishes from a wide range of restaurant around the city. Service providers may be responsible for the order, the delivery and the payment or they may simply provide the platform. In the latter case the delivery and the payment are responsibility of the restaurateur

E-commerce, which stands for electronic commerce, is a term that appeared in the business vocabulary in the 1970s and it is employed to identify any form of economic activity conducted via electronic connections.

In particular, R.T. Wigand states that e-commerce:

> "*denotes the seamless application of information and communication technology from its point of origin to its endpoint along the entire value chain of business processes conducted electronically and designed to enable the accomplishment of a business goal. These processes may be partial or complete and may encompass business-to-business as well as business-to-consumer and consumer-to-business transactions*" (Wigand, 1997).

Nowadays the technologies that mutually or individually are necessary to the existence of the electronic commerce are roughly 30, including the ICTs.

While some service providers, such as Ebay, act as intermediaries, offering just a dedicated platform and electronic payment systems, others, such as Amazon, have complex logistics and delivery systems and offer products under their own brands.

E-banking options in Italy are currently provided by almost all the operators, such as banks, credit institutions and investment banks. Besides having lower management costs and being faster, e-banking has the main advantage of being usable everywhere and every time. This service, consequently, helps to the user to save time and money, avoiding queues in the bank and the travel to reach it. Nowadays these e-banking services are offered in every developed country, irrespectively of the smartness of the city.

In this context space sharing services include coworking and home sharing.

Coworking, intended as the sharing of the physical working spaces among workers that do not belong to the same company, is becoming more and more widespread in recent years. Different subjects are attracted by coworking: independent researchers and scientists, contractors, work at home professionals and also companies, usually startups that doesn't have still found (or cannot still afford) an office accommodation. Coworking places are fully equipped to support work, and can be booked and checked in real time using dedicated applications.

Home Sharing is a new alternative way of renting houses or rooms that is becoming widespread in Italy. Web platforms, provided by many operators, allow the meeting between supply and demand of renting space. Usually the renter is not an operator of the hospitality industry, but he is simply an individual with some extra-space. Many additional services are often offered: from the traditional hotel services, such as cleaning, housekeeping and catering, to more innovative ICT-enabled services, such as self check-in and check-out**.**

3.2.2 Smart People & E-Education Services

The Smart People & E-Education category includes:

- *smart services for citizens participation and social cohesion;*
- *e-learning and other e-education services.*

Smart services for citizens employ IcTs in order to improve the social fabric, and in particular social cohesion. An example is provided by My Neighbourhood - My City, a public-private partnership project launched in meany European cities (among which Milan) by the Competitiveness and Innovation Framework Programme (CIP) of the European Union. The project is aimed at improving the closeness between the public institutions, particularly the Municipality, and people living in problematic districts. The project involves also the creation of an open platform that employs gamification techniques to stimulate people to get actively involved with their own neighbourhood, and that is able to collect data also from other existing applications. The collected data are intended to be used to re-design and co-design services in order to adapt them to the needs of the community for the purpose of improving the quality of life of the district and helping people to connect each other.

Accordig to the researchers (Ghasemi and Hashemi, 2011) the employment of ICT in ***educational services*** is meant to:

- improve the quality of learning and taught;
- increase the accessibility and quantity of available information;
- enable a rapid access to information;
- cut the educational expenses;
- increase the accuracy and quality of scientific texts;
- stimulate the interest of students;
- create learning experiences and increment learning opportunities;
- improve the dynamics between students and educators.

The employment of ICT for educational purposes is also embodied by the concept of ***e-learning***, which can be indicated with other terms such as distance education, online learning, computerized electronic learning, internet learning and many others. However e-learning is defined by the North Carolina Education Cabinet as a way to learn "*utilizing electronic technologies to access educational curriculum outside of a traditional classroom. In most cases, it refers to a course, program or degree delivered completely online*". E-learning, in all its form, is typically employed in several universities.

3.2.3 Smart Governance Services

The category of Smart Governance & City Administration includes:

- *digitalization of the public administration and management of documents, archives, print and similar;*
- *Free open data from the P.A..*

The ***services of digitalization of the public administration*** are closely related to the concept of e-governance. Their aim is to improve and simplify public services, to increase their accessibility and transparency as well as to increment the involvement of the citizens in the decision making process.

These aims are met by enabling citizens to undertake and complete all the administrative and bureaucratic procedures via dedicated applications and web portals. The completion of the procedures needs often the implementation of electronic payment systems as well as digital identies and systems for the electronic authentication. For example, the Italian Government in 2012 implemented, through Agenzia per l'Italia digitale (AGID), pagoPA, an electronic payment system that all the public entities and administrations as well as many banks and payment institutions are required to use. SPID (Sistema pubblico di identità digitale) is the electronic authentication system of digital identity employed by the P.A. and implemented by AGID.

In addition, local governaments guarantee ***free access to data*** concerning public organizations, territory, population, urban services, economy and administration through a dedicated internet portal and applications. The purpose of this service is to provide free open data to businesses, academia and researchers as well as to citizen.

Exmaples of the implementation of these servies are the Helsinki Region Infoshare Project, devevolped n Helsinki, and the Open Data BCN project in Barcelona.

3.2.4 City Administration Services

The category of City Administration includes several UFM services, such as:

- *management and maintenance of smart buildings and of their systems;*
- *management, operation and maintenance of heat station and heating systems;*
- *management, operation and maintenance of air treatment systems;*
- *management, operation and maintenance of clean water and sewage systems;*
- *management, operation and maintenance of electrical and lightening technologies systems;*
- *management, operation and maintenance of smart grids;*
- *management, operation and maintenance of the technological security systems;*
- *management, operation and maintenance of technological control systems;*
- *management, operation and maintenance of elevators and lifting systems;*
- *waste collection and disposal management.*

The aforementioned UFM services related to the management of the resources, such as smart grid systems, smart meters, smart water, sewage management and, more in general, of the urban properties described in Chapter 2. Many UFM services can be part of complex integrated resource management systems. The latter, which have been adopted on many smart cties (Hamburg, Barcelona and Copenhagen among them), employ IoT and ICT in order to save resources and thus costs, by achieving a better, more efficient and integrated resource management. Despite the fact that these systems, as well as many of these UFM services, have a direct or an indirect impact on the environment, they are presented here among the Smart Governance & City Administration Services and not among the Smart Environment Services.

The ***services of management and maintenance of smart buildings*** *and of their systems* are those related to the implementation of ICT and IoT systems for the buildings management ad maintenance activities. These services are aimed at reducing and monitoring energy consumption (and thus pollutant emissions) levels as well as maintenance costs thanks to more efficient and cost-effective solutions which employ ICT and IoT systems.

An example is provided by the Smart Building Management System Project, developed in Amsterdam, which consists of the substitution of traditional lamps of office buildings with light-emitting diode (LED) lighting and subsequently involves the installation of smart plugs. Smart plugs are able to measure the energy within an outlet and to automatically switch off devices.

Another example is the Digital Home Environment Energy Management System (DEHEMS), a system developed in Manchester City which is composed of smart meters and the use of a graphical user interface that are able to record and show to the user the energy performances in real time, thanks to real-time power measurement. The system provide the user with reports and analysis of the energy performances in order to enable a more efficient management of the energy consumption.

Media-tic Building instead is an example of building designed to employ ICTs. Located in Barcelona, the building's façade is made up of ethylene tetraflour, an innovative and translucent covering material, and is at the same time a mobile sunscreen and an external covering. The system works thanks to luxometer sensors that are able to automatically and independently adjust the level of temperature and sunlight.

Smart metering services consist of the installation of smart meters for the monitoring of the consumptions of electricity, water and gas. Smart meters are able to connect to wireless networks, in order to be consulted in real time by users, through devices like smartphones and computers.

Smart water management services refer to the real-time monitoring of water levels, quality and the existance of leaks and problems in the distribution system. These systems employ smart sensors and smart meters, located in points of use (PoU), in order to measure and monitor the level and presence of water of strategic points of the distribution system (Shahanas and Sivakumar, 2016). The data collected are transmitted, through WiFi and Bluetooth technology, to a local server. The data are then analyzed by a central system, which can be a low cost full functional computer with WiFi connectivity, in order to be visualized by end users through web interface. The systems can also include email or SMS alert systems.

Smart sewer management services are related to the design of innovative smart sewer management systems. These systems are equipped with smart sensors, which enable them to monitor in real time many parameters such as, for example, the actual pipe water levels or the pumps status. An example of a pilote smart sewer management system can be found in the city of Newcastle upon Tyne (Edmondson et al., 2018).

Different typologies of sensors cen be employed in sewer management systems, such as precipitation gauges, water level, water velocity and quality sensors. In particular, precipitation gauges are designed to keep track of local rainfall and snowfall and to resist to the wind action. The quality of sewage water is usually assessed by the biosensors embedded in the sensors, which are able to detect the presence pollutants such as nitrogen, ammonia and phosphorus. Water level and water velocity sensors usually employ similar technologies, namely ultrasonic emissions, radar, laser and pressure transducers, the latter being used more frequently in water level sensors. Both water level and velocity sensors are installed in manhole chambers at fixed positions, usually strategic positions due to their costs, especially with reference the ultrasonic level sensors. These sensors, particularly those measuring the level, quality and velocity of water, need to be waterproof and provided with long lifespan battery technology.

In order to be able to send their position, most of sesors employed in sewer management systems are equipped with GSM Short Message Service (SMS), GPS modem or Cell_ID with triangulation.

The data collected are sent to the central system which elaborates them in order to inform the user about the occurrence of asset failure, like blockage or collapse, and service failure, sch as flooding or pollution. In particular, the data coming from the sesors can be used to predict the likelihood of flooding.

The ***services of management, operation and maintenance of smart grids*** refer to the implementation and of smart systems for the resource management, such as the the smart systems for the distribution of electricity, gas and water. While This service category may appear similar to other ones, like smart water management services, on the contrary it is on the top of the others and may include them. In fact, it is characterized by a broader vision, being focused on the whole grid.

These services employ several smart technologies, like, for example, the aforementioned smart meters.

Management, operation and maintenance of electrical and lighting technologies systems services are UFM services that are aimed at increasing the savings of money and energy by improving the public street lighting systems performances and consequently at reducing the environmental impact. This new approach consists mainly of the substitution of all the conventional street lamps with LED technology-based lamps or in order to reduce carbon dioxile emissions, energy consumption and light pollution (due to directional light) and to increase the lifespan and the quality of lights. LEDs are able to significantly increase the efficiency of the public lighting system by reducing the energy consumption up to 40%. For example Los Angeles in 2013 reduced of the 63% the costs of energy, thus saving $8.7 milion, by replacing the traditional streetlights with 140000 LED street lights (Marino et al., 2016). Similarly, in 2014 the city of New York replaced 250000 traditional lamps and saved $14 milion.

It is also possible, although rare, to insall LED lamps with environmental sensors embedded in them and managed in remote by an external software. The sensors are able to collect data concerning the environment (temperature, humidity, air pollution, noise ecc), the traffic and the presence of people and transmit them to the central system where they will be monitored and elaborated.

This is the case of Barcelona for example, where data gatherd by sensors are sent to central units, the Control Cabinets, in the streets, which manages them together with other services, such as optic cable connections or electrical vehicle charging stations. The data collected by the Control Cabinets are sent via Internet to the Control Centers where they will be processed and managed.

Data could be used, for example, to elaborate new and more accurate dimming percentages for the lightening system because working constantly in full power is not efficient.

However it important to notice that very few street lights are currently connected and remotely managed by a software, at 2016 they were estimated to be the 1% of the street lights of the whole world.

Management, operation and maintenance of the technological security systems services include all the services that provide security and privacy systems, such as video-surveillance systems, which employ multimedia and networking technologies. Data are collected by sensors, such as cameras, and then sent to the central systems where they can be processed by softawares or by human users. Sophisticated systems can be equipped with several typologies of sensors like motion or heat sensors. This systems requires wireless network able to support the transmission of a vast amount of multimedia data produced by the sensors (Balasubramanian et al., 2017). In addition, the transmission of big data has to secured by employing video encryption algorithms, because the confidentiality of data during transmission is very important in this context.

These sytems are employed both by privates to control properties, buildings and assests and by the public authorities. In particular, integrated security systems are used by the local authorities and the police to control and monitor in real time the territory in order to prevent and fight crime and the social degradation. Currently, many cities and towns all over the world invest financial resources to install video-surveillance systems, often able to perform facial recognition. An example is provided by the 360 degrees wireless cameras that can be seen in most of the Italian cities and towns.

Waste collection and disposal management services are based on IoT systems for the collection of waste that are currently tested in many smart cities around the World. These systems are aimed at improving waste management, in particular waste collection and disposal activities by making them more substainable and efficient.

An example is provided by the system tested in the city of Copenhagen (Gutierrez, et al., 2015). This sophisticate system consists of trashcans or containers equipped with wireless sensors that are able to collect and transmit data concerning the waste volume. Trashcans employ sonar technology-based sensors to measure the distance between the top of the trashcan and the level of waste. However other additional sensors can be installed as well, such as those measuring temperature, humidity, weight and motion.

The data collected are transmitted, through WiFi technology, to the server, where they are processed and analyzed through optimization algorithms. Additional data related to time stamps and GPS locations are collected by trash trucks' in-vehicle sensors. These data combined with those collected by the trash cans are combined and analyzed by route optimization algotithms, such as the Shortes Path Spanning Tree (SPST). The results are subsequently sent to the smartphones, the tablets of the trash collectors and to the navigation systems of their trucks. Thus, trash collectors are informed on a daily basis of the best and most efficient route to follow to collect waste.

Although more expensive than traditional systems, with an increase of the daily collection cost that ranges between 13% and 25%, innovative systems can increase the quality of life of a city and the sustainability of the waste management service.

3.2.5 Smart Mobility Services

Mobility is a key field for a city and, in particular, a smart city is a very favourable environment the implementation of many typologies of ICT-based services.

Concerning UFM it has been reported services of:

- *maintenance and monitoring of road surface markings, vertical road signs and luminous road signs;*
- *verification, monitoring and control of the road network;*
- *maintenance of road surface and quick response for dips;*
- *operation and maintenance of smart traffic monitoring systems;*
- *operation and maintenance of smart parking.*

The UFM services related to the road surface and road signs and light maintenance and control employ the in-road sensors described in the previous paragraph.

Smart traffic monitoring systems are ICT-based systems aimed at effectively managing city traffic in order to to regulate traffic, improve its flow and to avoid congestions, with all their consequences (from socio-economic as well as environmental point of view), as well as to improve and make resilient transportation networks. These systems usually employ in-road and sometimes also in-vehicles sensors and GPS. The data collected are received and processed by the central system and then the information reach the user trough dedicated smartphone application or web interface.

For example, the city of Zaragoza offers to its citizens detailed city traffic information, thanks to the data collected and elaborated by a sensor-based traffic management system. This service, thanks to real-time traffic information, enable, at the same time, decision makers to perform efficient traffic management decisions and users to choose the best journey. The system employs 150 in-road sensors and is able to monitor 90% of the urban routes. The information collected is sent to the Traffic Management Centre of Zaragoza City Council and showed on a web interface.

The city of Enschede instead has installed a system that aims at optimizing the use of the road network by informing the users, through dynamic route panels, about the travel time savings. The actual vehicles' time travel are collected by inductive loop detector sensors installed in proximity of traffic lights.

An example of city that adopt a system based on in-vehicles sensors is Eindhoven. In-vehicle sensors placed on pilot cars ghaters data and tansmit them to the cloud-enabled traffic centre.

The city of Thessaloniki implemented a system that, by collecting real-time data, is able to manage incidents and traffic lights in real time. It can also make short-term predictions of the traffic situation and of the the travel times. This information is also employed by a journey planning service offered to the uesers.

The city of Copenhagen, instead, extracts part of the data necessary to feed its traffic monitoring system from the bicycles owned by its citizen. In fact, the project called The Copenhagen Wheel enable every bicycle to become smart and electric by installing MIT-designed device which consists of an electric engine and some sensors. The electric engine is able to produce a 100 Watt power to help the user, and the sensors allows the user to manage the engine and to locate and monitor the bicyle. These sensors are also employed by the Municipality of Copenhagen to collect traffic data that are sent to the traffic monitoring system.

***Smart parking* services** consist of several services provided both by the Municipalities and by privates, thus being both UFM services and not-UFM services, that help the user to find parking lots or to manage the parking fees. These services may employ sensors, deployed within transportation networks and buldings, that collect information about free parking lots and then, through wireless technology, send it to data centers that, in turn transmit it in real time to the dedicated applications in the users' smartphones. An example is provided by the Smart Parking Network Barcelona, developed by the city of Barcelona and aimed at optimizing the use of the existing parkings lots, at reducing the time to find parking and at cutting the emission and the noise pollution. Additionally or alternatively, many services help the user to carry out and simplify all the procedures related to the parking fee payment and enbles him to perform such activities through his smartphone. Another example is provided by EasyPark Group, which offers its services in more than 700 cities, such as London, Amsterdam, Berlin, Milan and many others. Easypark dedicated app provides users with all the information concerning the locations of all the parking lots, the locations of the restricted access areas and memorizes the place where the user had parked his car. In addition, the app enable the user to pay for the parking fee via smartphone, thus avoiding the user to waste time searching for a parking meter.

Among the not-UFM services, either public or private, it has been reported:

- *car sharing, scooter sharing, bike sharing and carpooling services;*
- *autonomous transport services,*
- *journey or trip planning services,*
- *electric vehicles charging stations services,*
- *smart parking services;*
- *smart public transport services.*

Car, scooter and bike sharing services are based on a model of vehicle rental that spread quickly in recent years and that are currently offered in many cities all over the world. Organizations, usually public or private operators, rent their vehicles for short periods of time to users who had subscribed the service in a predetermined service area. Users can be both individual and companies and thus the service can be both business to consumer (B2C) and business to business (B2B).

The currently existing vehicles sharing services can be classified as station based and free floating. In a station based service the users have to pick up vehicles in dedicated parking lots and, after the use, leave them in dedicated parking lots, not necessary the same where vehicles have been picked up. Free floating instead refers to a sharing service in which the vehicles can be parked everywhere and users locate, through a dedicated app, the one that is closer to them.

These services employ in-vehicle sensors and GPS technology to gather data concerning their position, their status and usage. This information is then provided to the user usually through a dedicated smarphone application which allows also him to book the vehicle and to pay for it.

In many cases these sharing services are integrated in a broader mobility services offer, as in the case of the cities of Vienna and Graz. In these cities car sharing and bike sharing services are part of the integrated transport service eMorail, which is meant to help commuters in their daily commuting, without owning a vehicle.

The concept of ***carpooling*** instead consists of the sharing of car journeys between people with the same destination, so that only one person uses his own car. For this reason, carpooling is alternatively called ride-sharing. Carpooling is very effective in avoiding or reducing fuel costs, carbon emissions, tolls, the stress of driving, street congestions and scarcity of parking space and thus it brings advantages both to individuals and to the society. It can be both B2C and B2C because it may address both individuals and companies. In fact, for medium and large companies it can be a useful tool to manage the mobility of their employees.

Autonomous transport refers to those transport services that employ autonomous vehicles, the latter being defined as "*vehicles that have at least some aspects of safety-critical control functions (such as steering, throttle, or braking) that occur without driver input are vehicles that doesn't need human inputs to navigate*" according to the U.S. Department of Transportation. These vehicles are able to perceive the surroundings environment thanks to the combination of different technologies, such as sensors, laser lights, GPS, odometry, radar and computer vision. The data are then elaborated and interpreted by sophisticated control systems that enabled the vehicle to move autonomously.

Autonomous transport can be both for people and for freights and can work with vehicles operating on roads, on tracks or on dedicated guideways. The latters has already been implemented in the form of a huge variety of automated guideway transit (AGT) systems.

An example of automation on dedicated guidelines, is the Morgantown Personal Rapid Transit, a PRT (personal rapid transit) system which operates in the city of Morgantown since 1975 and it consists of wheeled vehicles with automated doors that serves five stations following a dedicated guideline. Automation on tracks is more popular than that on guidelines, especially in the form of subway lines. The first driverless subway line was open in London in 1967 and today many fully automated GoA 4 (Grade 4 of Automation) subway lines exist, like for example that of Barcelona, Honk Hong, Vancouver and Sao Paulo (International Association Of Public Transport, 2012).

The remaining part of this section is dedicated to the on road and “free” automated transport, which is currently under development, thanks partially to the improvement of the ICTs.

The Society of Automotive Engineers (SAE) International established, in the work *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* (SAE International, 2016), a classification system based on six levels of automation, ranging from no “driving automation” (level 0) to “full driving automation” (level 5). The definition of the levels is based on how the motor vehicle driving automation systems perform the dynamic driving task (DDT).

“Driving automation system” is a general term that defines to any hardware and software that are able to perform part of all the DDT and it is used for all the six levels. On the contrary the term “Automated Driving System (ADS)” refers to levels 3, 4 and 5, in which the automated systems acquire the complete control of the car performing the entire DDT.

Level 0 – No Driving Automation. The driver performs all the DDT, and may be supported by active safety system, such as system warning of an impending crash or traditional fixed-speed cruise control.

Level 1 – Driver Assistance. The driver performs many of the DDT. He supervises the driving automation system and decides when activate or disactivate it. The driving automation system performs the remainder of the DDT not performed by the driver, controlling the longitudinal or the lateral motion, however the driver is always ready to take the full control of the car. The technologies employed in this level are usually adaptive cruise control and lane-keep technology.

Level 2 – Partial Driving Automation. The driver performs part of the DDT not performed by the driving automation system, supervises that system and decides whenever activate or disactivate it. The system performs the remainder of the DDT and, as opposed to level 1, it controls both the lateral and the longitudinal motion subtasks. The driver is always able to immediately performs all the DDT. Vehicles of level 2 employ two or more advanced driver assistance systems (ADAS) that must be able to act in a coordinated fashion. Examples of ADAS technologies includes active lane-keep assist, adaptive cruise control, steering or acceleration control and automatic emergency braking.

Level 3 – Conditional Driving Automation. The driver verifies the operational readiness of the ADS, decides when to activate it and then he constantly monitors it. The ADS, once engaged by the driver, performs all the DDT and evaluate when to issue a request to intervene to the driver due to performance-relevant system failure. The ADS is able to perform the DDT only if the tasks are within its Operational Design Domain (ODD), otherwise the system issue a request to intervene. The driver has to promptly retake control of the vehicle after the disengagement of the ADS. This level employs sophisticated sensors, software and hardware. However, this automation level is not considered totally safe, due to the fact that it requires a vigilant driver to constantly monitor its functioning. In 2014 Waymo, a subsidiary of Google, stopped the experimentation on level 3 because of the unreliability of the human drivers.

Level 4 – High Driving Automation. The driver performs the DDT or monitors the ADS only when requested by the system, otherwise he becomes a passenger. He may request the disengagement of the system. The ADS can be engaged only within its ODD, it needs a pre-defined trip. Once engaged, the system performs all the DDT, monitors its own performances, decides whenever disengage or not. It may also delay the request of disengagement of the driver and it is able to operate even if the driver doesn't respond to the request to intervene.

Level 5 – Full Driving Automation. The driver performs the DDT or monitors the ADS only when requested by the system, otherwise he becomes a passenger. He may request the disengagement of the system. The main difference with the previous level is that the ADS is able to perform all the DDT under all circumstances, regardless the journey, the traffic situation and the speed. Once engaged, the system performs all the DDT, monitors its own performances, decides whenever disengage or not and it may also delay the request of disengagement of the driver. As in level 4, the system is able to operate even if the driver doesn't respond to the request to intervene.

The technology employed by the autonomous vehicles may be categorized in two ways, hardware and software, working together at the same time.

The hardware, which can be seen as the "body" of the system, consists of:

- *Sensors*. They enable the autonomous vehicle to collect raw information from the environment. Each sensor has its own advantages and disadvantages and, thus, in order to compensate this fact, different sensors are employed at the same time. This process is called sensor fusion and it is aimed at obtaining extra redundancy by compensating the disadvantages of the different sensors. The most important sensor employed are the GPS/Inertial Measurement Unit (IMUs), LiDar, camera and radar.
- *V2V And V2I Technology (V2X Technology)*. It stands for "vehicle to vehicle and vehicle to infrastructure" technology. It allows the vehicle to communicate and to transmit the information, acquired through the sensors, to other actors, such as other vehicles, city lights and so on.
- *Actuators*. They are the elements that execute the tasks issued by the software and, thus, they are responsible for controlling and moving the vehicle.

The software, which can be seen as the "brain" of the system, can be subdivided into three sub-systems:

- *Perception*. The aim of this sub-system is to analyse the raw information, coming from the sensors and the V2V technologies, and to understand its meaning. The perception sub-system allows the vehicle to perceive the surrounding environment, such as obstacles, pedestrian, cars and so on.
- *Planning*. It enables the driving system to make decisions in order to achieve higher order objectives. The action to take is decided by combining the processed information, coming from the perception system, with the pre-determined policies and rules about the navigation in the environment.
- *Control*. This sub-system is aimed at transforming the decisions taken by the planning sub-system into action. In particular, the control sub-system communicates to the actuators of the hardware the inputs needed to obtain the desired motions.

Many tests are currently performed in different Countries, all over the World, but in Italy no test has been already undertaken. However, recently, the Minister of Infrastructure and Transport allowed the testing on autonomous vehicles in Italy, with the Decree of February 28, 2018, also known as "Smart Road decree".

Journey or trip planners are platforms that helps users to find the optimal means of travel between two or more locations, by aggregating and combining all the mobility options in a city, from sharing vehicles to taxis and public transport. In addition, many of these applications offers integrated services which allow the users to book and pay in advance for their trips. This type of services can be offered both by the administration and by the private sector and it employs ICT to integrate different urban means of transport in order to optimize travel time and to decrease emissions and traffic congestion.

An example is provided by the integrated public transport system of the city of Copenhagen which, besides optimizing the public transport systems, offers an electronic journey planning service. The electronic ticket, or Travel Card, is read by a sensor and then the cheapest and shortest journey is communicated to the user. In addition, the cheapest price is automatically debited from the Travel Card.

Another example is the SMILE platform, developed in Vienna, which, besides enabling the coordination among the major Austrian public transport service providers and other private mobility service providers, offers a journey planning service. This user-friendly platform, implemented in Vienna, helps the user to chose the best journey to reach his destination, books the necessary means of transportation and pay electronically the ticket for them.

Finally, the city of Thessaloniki implemented an electronic mobility planner that informs in real-time citizen about traffic conditions, allowing them to choose the best journey, in terms of length, cost and environmental impact.

Several different services can be classified as ***smart public transport***. Municipalities and urban public transport companies may use ICTs to improve the public transport offer by developing electronic tickets (that can be payed and booked via smartphone) or by introducing smart tickets such as Travel Cards. The electronic ticket is valid for all the public means of transportation offered by the city such as trains, metro, buses, cars and bicycles. An example is provided by the city of Copenhagen which developed a public transport system aimed at improving the travel experience of the users by minimizing the travel time and by optimizing the physical coonection between the different modes of transportation. The city adopted the electronic ticked and a Travel Card and developed also an electronic journey planner, which will be described in the following lines.

Another example of smart management if the public transport is the eMorail project, which is an integrated transport service intended to be a environmentally friendl and cost-efficient solution for commuters. eMorail requires the prior purchase of a train ticket for the Austrian Federal Railways and provides to user an intermodal electronic car and bike sharing and detailed real-time information about the situation of the public means of trasport. The services can be accessed by smartphone applications.

Finally, SMILE is a multi-modal mobility platform which implemented the coordination between the largest Austrian public transport providers, Wiener Stadtwerke, Wiener Linien and the Austrian Federal Railways (ÖBB). This is platform, developed in Vienna, has open interfaces and it has an high level of scalability and thus it attracts many other mobility service providers (such as car and bike sharing or smart parking services) thereby widening the offer of services.

3.2.6 Smart Environment Services

The Smart Environment category encompasses indirectly a large number of services that have been already included in other categories, especially among the Smart Governance & City Administration Services. For example developing a traffic management system or improving the management of the resources led to a positive impact on the environment.

For this reason, the only services that have been reported are those related to the ***air quality and pollution management***. As already described in the previous paragraph, the sensors employed by the measuring stations are usually able to detect the presence and measure the quantity of chemical substances in the air such as suphur dioxide (SO2), oxides of nitrogen (NO, NO2, NOX), oxides of ammonia (NH3), particulate matter (PM10 and PM2.5), carbon monoxide (CO), ozone (O3), benzene, toluene, xylenes and black carbon.

Measuring stations, such as those of the Agenzia Regionale Per La Protezione Ambientale (ARPA), are designed to be modular, in order to be flexible and to be able to easily increase or decrease the number of paramether measured. The station is included into a fiberglass box, and the measuring modules are provided with storage units which collect the sensed data and transmit them to the central system for their elaboration.

3.2.7 Smart Living, Culture & E-Health Services

The category Smart Living, Culture & E-Health includes several cultural services and health services:

- *remote and teleassistance, medicines home delivery and other health services;*
- *digitalization of museums and historical archive collections and other cultural services.*

Cultural services are defined as *"Services aimed at satisfying cultural interests or needs. They do not represent cultural material goods in themselves but facilitate their production and distribution"* according to the UNESCO (UNESCO Institute for Statistics, 2009).

These services may employ ICT in different ways, an example is the ***digitalization of museums and historical archive collections***. For instance, as to 2018, 61% of British public museums and up to 50% of their collection have already been digitalized while the 50% of digitalized collection have been already made available online (Department for Digital, Culture, Media & Sport, 2018).

The aim of the digitalization is to elaborate and adopt a strategic, coordinated and integrated approach in the digitalization, in order to provide a curated, easily accessible and discoverable content to the audiences as well as to stimulate their interest.

ICTs can be also employed by e-health services, which, according to the Ministry of Health, are mainly reated to:

- the support for the monitoring of the levels of standard healthcare provision (LEA) through the integration of the local information systems;
- the increase in efficiency in the healthcare thanks to the improvement of the coordination among healthcare professionals;
- the support to the integration of healthcare services and to home care services;
- the impovement of the accessibility of healthcare services;
- the support to improvement of the management of the healthcare facilities;
- the control of the health expenditure through a better healthcare monitoring.

A practical example of home health care platform can be a 3 layered IoT-based open platorm, with embedded sensors, that communicate through WAN, GPS or 3G technology.

Another example is provided by Health Lab, which is a project developed in Amsterdam based on a network of living labs and aimed mainly at creating an integrated IoT-based platform.

For what concerns home care services, several important services can be included in this sub-category. For instance, ICTs found application in ***remote and teleassistance services*** as well as in ***medicines home delivery services***.

In fact, ICTs are being employed in recent years by operators that, through dedicated web portals and applications, act as intermediary between users and pharmacies (according to the Italian Law medicines obtainable with a prescription has to sold by pharmacists), offering home delivery services of drugs and medicines.

3.2.8 Smart Communication & ICT-Infrastructure Services

The Smart Communication & ICT-Infrastructure category includes among others:

- *management, operation and maintenance of broadband and ultrabroadband, phone and data transmission networks;*
- *free WiFi and cellular mobile communication technologies.*

These services are of crucial importance, since the ICT network is the backbone of a smart city and it is vital for the development of ICT-based services.

Wireless communication technologies have been already treated and described in chapter 2.

Concerning the wired data transmission networks it is worth to focus here on the broadband and on the ultrabroadband. Although different definitions exist, in Italy it is common practice to use the term broadband for fixed networks when the speed transmission is lower than 30 Mbps, while when the speed transmission is higher than 30 Mbps the term used is ultrabroadband.

A typical example of broadband is the ADSL (asymmetric digital subscriber line). The cables that connect the service provider's station with the user are copper pairs and the speed transmission is usually between 7 Mbps and 20 Mbps.

Ultrabroadband is generally referred to fixed networks that employ the optical fiber technology. Several typologies of fiber-optic communication solutions exist, depending on the materials of which the cables are made of. The cables used to connect the service provider's station and the street cabinet are always made of optical fiber, but the final user can be reached in different ways.

Among the several possible and sometimes similar solutions, the most important are:

- fiber-to-the-cabinet or FTTC (similar to fiber-to-the neighborhood, FTTN and to fiber-to-the-street, FTTS): the cables that connect the street cabinet with the user are made of copper pairs. The speed transmission of this solution ranges from 30 Mbps to 100 Mbps;
- fiber-to-the-building (or fiber-to-the-basement) or FTTB: the optical fiber cables reach the building of the user and only the final route to the user is made of copper pairs. The speed transmission ranges from 100 Mbps and 1 Gbps;

- fiber-to-the-home or FTTH: the whole connection, from the station to the user, is obtained by optical fiber cables. Ths is the fastest typology of ultrabroadband and its speed transmission is higher than 1 Gbps. New and even faster enhancements of the FTTH technology, based on the PON (Passive Optical Network) technology, are currently under development and will be deployed in the future. PON-based technologies are GPON, XG-PON, XGS-PON and NG-PON.

Finally, it is interesting to notice that in Italy the AGCOM, the Italian Authority for Communications Guarantees, ruled that the term optical fiber can be used for advertising purposes only with reference to FTTB and FTTC. In other words mixed materials technologies, such as FTTC, can not be advertised as optical fiber (AGCOM, 2018).

3.3 Overwiev Of The Sensors Most Commonly Employed By The ICT-Based Services In The Smart City Context

This section contains a brief overview and description of some types of sensors, which can be considered particularly noteworthy with respect to their application in the ICT-based smart city services presented in this chapter.

Before starting to list the sensors, it is important to notice that the majority of the sensors that will be treated in the following lines are employed in many other smart city's applications and ICT-based services, which, for the purposes of this dissertation, are too numerous to be listed in this section.

As already mentioned in chapter 1, since the birth of the term IoT, the **Radio Frequency IDentification (RFID)** have had a great importance and have been massively used in different applications.

RFID technology was initially developed during WWII, but since then it acquires a great importance in civilian applications, from access control and identity authentication to supply chain management and object tracking.

For example, the object to be tracked is provided with an RFID tag which is perceived by the reader and the information concerning the presence of the object is then stored. Similarly, in the access control application tags are attached to the authorized objects and authorized people is provide with tags-embedded cards. The reader in this case authorizes the the access to people or objects only if detects the presence of the tag.

This technology is composed by two main elements: tags and readers (Sethi and Sarangi, 2017).

Tags, which consist of small chips provided with antennas, are aimed at storing data and transmit them through audio waves, so that they can be received by the readers. Although it may seem similar to bar code technology, it is different because readers are able to receive data without a human operator and don't need a line of sight communication with the tags. Depending on the frequency, tags are able to transmit data to readers within a range of hundreds of meters.

RFID tags can be both active and passive, the former having a power source while the latter having none.

Passive tags are cheaper and have a wider lifespan because they get power directly from electromagnetic waves emitted by the reader.

Two main typologies of RFID technologies exist: near and far. In the former typology the reader generates a magnetic field through a coil in which alternating current is passed. Another and smaller coil placed in the tag generate a potential because of the ambient changes in the magnetic field. This voltage is paired with a capacitator so as to accumulate the charge necessary to power up the chip of the tag. Finally, the tag is able to generate a magnetic field in order to encode the signal that has to be firstly transmitted to and then picked up by the reader.

In the far RFID both the readers and the tags are provided with a dipole antenna. The one on the is meant to emit electromagnet waves, while that on the tag produces an alternating potential difference when powered up. This power is then employed to transmit signals.

As it has been already showed in the previous sections of this chapter, several services related to the fields of mobility, traffic and transportation management and street maintenance are offered in a smart city. This fields in fact are very important for a city and, thus, these services are both UFM services and not-UFM smart services.

The sensors employed in these fields are usually divided into in-vehicle and in-road sensors. The former are installed directly in vehicles while the latter are placed close to a road or embedded in it.

Many typologies of **in-vehicle sensors** are currently installed and employed in several activities and services. (Abdelhamid et al., 2014; Guerrero-Ibanez et al., 2018).

Table 46 shows the main typologies of in-vehicle sensors with their descriptions and some examples.

Typology	Description	Examples
Safety	They work almost in real time and focus on recognizing accident hazards and events.	Micro-mechanical oscillators, speed sensors, cameras, radars and laser beams, inertial sensors, ultrasonic sensors, proximity sensors, night vision sensors, haptic.
Diagnostic	In order to find any malfunction of the vehicle, they focus on collecting data for providing real-time information about its status and performance.	Position sensor, chemical sensors, temperature sensors, gas composition sensors, pressure sensor, airbag sensor.
Traffic	They are aimed at improving the traffic management by controlling the traffic conditions in specific zones and collecting data.	Cameras, radars, ultrasonic, proximity.
Assistance	They gather data for supporting comfort and convenience applications.	Gas composition sensor, humidity sensors, temperature sensors, position sensors, torque sensors, image sensors, rain sensors, fogging prevention sensors, distance sensors.
Environment	They monitor the environment conditions in order to provide drivers and passengers with alert and warning services that are used to enhance their trips.	Pressure sensors, temperature sensors, distance sensors, cameras, weather conditions.
User	They monitor the driver in order to detect abnormal health conditions and behaviours that can deteriorate the driver's performance.	Cameras, thermistors, Electrocardiogram (ECG) sensors, Electroencephalogram (EEG). sensors, heart rate sensor.

Table 46: *In-vehicle sensors: typologies, descriptions and examples. Sources of information: Abdelhamid et al., 2014; Guerrero-Ibanez et al., 2018.*

As it can be seen from Table 46 the purposes of the in-vehicle sensors are not limited to the autonomous vehicle topic, but they are necessary to cope with issues such as traffic and parking management, emissions and environmental protection and many others. Thus, for the aim of the dissertation, it is useful to mention and describe in this section a many of the in-vehicle sensors showed by Table 46, which will be mentioned later in this paragraph concerning other services.

Pressure sensors are installed in the tires of vehicles and are aimed at monitoring the tire air pressure and at warning drivers through vibration, light or acoustic signals in case of low air pressure.

Proximity sensors allow the driver to notice objects when the vehicle approaches them, but their accuracy is badly affected by humidity and temperature.

Ultrasonic sensors are able to determine the distance between an object and a vehicle, warning the driver when the vehicle gets within a certain threshold.

Electromagnetic sensors inform the driver when an object gets in the electromagnetic field generated around the bumpers.

Radio Detection And Ranging (RADAR) is, together with *laser sensors*, a technology that is aimed at preventing potential collisions between vehicles and objects by alerting the driver, automatically activating brakes and regulating the throttle. This safety application constantly scans the front, the back and the sides of the vehicle and employs radio waves in order to calculate the distance between the sensor and the objects.

The *Inertial Navigation Systems (INS)* is used to improve the accuracy of the Global Positioning Systems (GPS). INS employ the *gyroscope* and the *accelerometer sensors* to collect parameters such as vehicle position orientation and velocity.

Speed sensors and *radars* are used in safety applications that warn the driver, through an acoustic alarm or a vibration signal, about potential dangers when behaviors such as changing lanes or wandering out of the lanes are detected.

Cameras are used for different purposes which involve the monitoring of both the driver's conditions and the road. In fact, they are used to identify the existence of erratic behavior of the vehicle, such as driving straight out of the line of the road, and to check the body posture, the head position and the eye activity in order to detect the presence of abnormal conditions such as signs of fatigue. Cameras are also employed in night vision assistance applications that enable the driver to identify objects, animal, persons and other obstacles on the road.

Concerning autonomous vehicles, *Light Detection And Ranging (LIDAR)* is one of the most important technologies for the development of automated driving systems. It provides robots and self-driving vehicles with some important attributes such as a constant 360-degree visibility and accurate information, enabling them to observe the worlds that surrounds them. Beams of laser light are continually fired by LIDAR sensors, which then measure the time the laser light takes to return to the sensor.

In-road sensors instead can be classified as intrusive and non-intrusive, according to the location where they are installed (Guerrero-Ibanez et al., 2018).

Intrusive sensors are installed on the pavement surfaces or embedded in them and they can be divided into three main groups, as showed in Figure 4:

a) *Passive magnetic sensors (magnetometers)* which are embedded in the road and connected to processing units, either wirelessly or wired;
b) *Pneumatic tube sensors* which are installed across the road and are linked to processing units, either wirelessly or wired;
c) *Inductive loops are wire coils* buried directly into roads that transmit data to processing units. They are the most employed in traffic control systems.

Intrusive sensors are characterized by high accuracy in the detection of the vehicles, but they have also many drawbacks such as traffic interruption during installation and high installation, maintenance and repair costs.

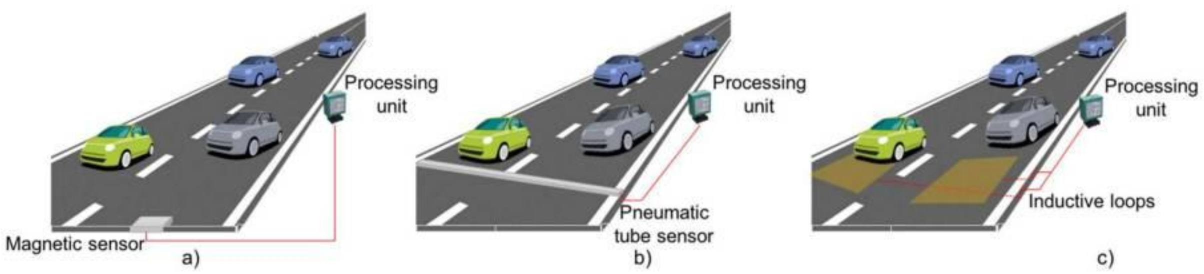


Figure 4: *Intrusive in-road sensors types: magnetic sensors, pneumatic tube sensors and inductive loops. Source of information: Guerrero-Ibanez et al., 2018.*

Non-intrusive sensors are usually used for the detection of vehicles' transit, speed and lane coverage. They are not installed on the pavement surfaces of the road like intrusive ones, but they can be found in different places that can be divided in three groups, as showed in Figure 5:

a) *Sensors mounted on a roadside mast* that are able to control a definite coverage area.
b) *Sensors mounted on bridges* that monitor the coverage are directly below them.
c) *Sensors installed road side on the ground level*. They use a beam that crosses the road. For this reason, they are subject to interferences and, thus, they are usually employed in single lane with unidirectional flows.

Non-intrusive sensors are mainly employed into systems that perform activities such as monitoring of the queue at a traffic light, traffic conditions in general and weather and road surfaces conditions.

With respect to intrusive sensors, the non-intrusive ones are more easily seen by drivers, resulting in a faster response time. In fact, the driver reacted faster by slowing down and using the correct lane and, thus, the non-intrusive sensors are often considered more effective in reducing the reaction time of the drivers.

However, they are more affected by bad weather and environmental conditions. In particular, rain, snow and fog are responsible for decreasing their accuracy and the quality of the information collected.

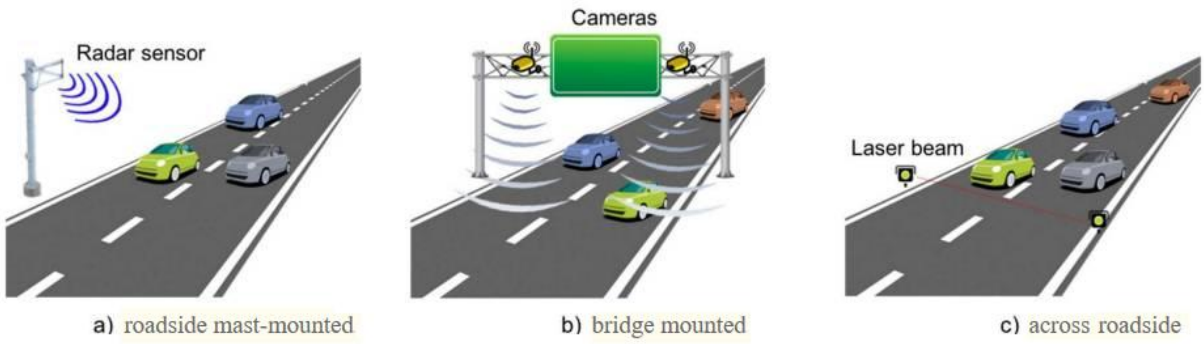


Figure 5: *Non-intrusive in-road sensors groups: roadside mast-mounted, bridge mounted and across roadside. Source of information: Guerrero-Ibanez et al., 2018.*

With respect to the traffic monitoring, Table 47 shows the main in-road sensors currently employed, both intrusive and non-intrusive, with their descriptions.

Typology	Sensor	Description
Intrusive	Pneumatic Road Tube.	They are used for recording the number of vehicles, the vehicle classification and the vehicle count.
	Inductive Loop Detector (ILD).	They keep track of the vehicle's movement, presence, count and occupancy. A device at the roadside records the signals generated.
	Magnetic Sensors.	They are able to detect the presence of vehicles and to identify stopped and moving vehicles.
	Piezoelectric.	They are used to classify and count vehicles and to measure vehicle's weight and speed.
Non-intrusive	Video Cameras.	Cameras are able to identify vehicles across several lanes and to classify them by their length. They can also report vehicle's presence, flow rate, occupancy, and speed for each class.
	Radar Sensors.	They measure volume and speed of the vehicles and detect their direction of motion. They are employed by applications for managing traffic lights.

	Infrared.	They are employed in applications for vehicular speed, length and volume measurement and lane occupancy.
	Ultrasonic.	They are able to track the number of vehicles, their presence, and occupancy.
	Acoustic Array Sensors	They are employed in the development of applications for measuring vehicle's passage, presence, and speed.
	Road Surface Condition Sensors	They gather information on the grip, the road conditions and on weather conditions such as the surface temperature, the dew point and the water film height.
	RFID (Radio-Frequency Identification)	They are employed, mainly in the toll management, for tracking vehicles.

Table 47: *The main in-road sensors: intrusive and non-intrusive. Source of information: Guerrero-Ibanez et al., 2018.*

As it has already been done for the in-vehicle sensors, it useful for the purposes of this dissertation to describe the sensors presented in Table 47.

Pneumatic road tube sensors consist of one or more tubes located across the lanes so that, as a vehicle's tire passes over the tubes, the sensors produce a burst of air pressure. The latter is subsequently converted into an electric signal and sent to a processing unit in order to enable the sensors to count vehicles and to classify them.

The *Inductive Loop Detector (ILD) sensor* is made up of a wire coiled so as to form a loop, placed into or under the pavement surfaces of the road. It measures the change of the electrical properties in the electrical circuit caused by the passage of vehicle over the sensor. ILD generate an electrical current that is sent to a processing unit. This sensor is one of the most commonly employed in the traffic management, being able to gather data concerning the vehicular speed, occupancy and length as well as the traffic flow.

Magnetic sensors are used to obtain data about length, speed, flow and occupancy of the vehicles and they are suited to be employed over bridges. These sensors detect vehicles by perceiving changes in the ground's magnetic field.

Piezoelectric sensors perceive vehicles passing over them by through a variation in their voltage. These sensors are able to check up to four lanes, and, usually, they are used together with ILDs sensors to develop piezoelectric systems.

Video cameras, which are usually installed at the roadside, allow to collect data related to the traffic flow. Video cameras together with computers and sophisticated software contribute to forming a Video Image Processor (VIP) system. The images recorded by the video cameras are elaborated, analysed and interpreted by the computers and the algorithm-based software: each frame from a traffic scene is compared to the successive frame in order to detect changes in traffic parameters such as flow volume and occupancy. As a result, images are converted in traffic data. However, bad weather conditions can negatively affect the quality of the performance of this system.

Radar sensors work by harnessing the reflection of low-energy microwave radiations by the objects within a certain zone. Two main typologies radar sensor systems exist:

- *Doppler systems* are able to record the number of vehicles and to calculate accurately their speed by using the frequency shift of the return;
- *Frequency-modulated continuous wave radars* emit continuous transmission power, like continuous wave radar, and they are employed to collect data concerning the flow speed, volume and presence.

Radars sensors can be easily installed, they operate on multiple detection zones and they are very accurate both on day and night. However, they are badly affected by electromagnetic interferences.

Infrared sensors are able to identify the energy, emitted by vehicles or other surfaces, by transforming the energy reflected into electric signal which are transmitted to processing units. Two main categories of infrared sensors can be identified:

- *Passive Infrared (PIR)* are employed in the collection of data concerning flow volume, occupancy and vehicle presence. They are based on the radiation's emission and the reflection.
- *Active Infrared (AIR)* are used to gather data such as traffic density, flow volume as well as vehicular presence, speed and classification. They work by measuring the reflection time through Light Emitting Diodes (LED) or laser diodes.

Ultrasonic sensors are able to find the distance between two objects by measuring how long it take to a sound wave, that has been transmitted at frequencies ranging from 25 to 50 KHz, to be reflected to the by an object. The energy produced by the reflected sound wave is transformed into an electrical signal and then transmitted to a processing unit. These sensors are very effective in gathering data about vehicle's flow and speed, however they are very sensitive to environmental conditions and effects.

Acoustic array sensors are going to replace magnetic and induction loop sensors to monitor and measure traffic volume, occupancy and average speed. Through a set of microphones, they are able to perceive the increment in sound energy, caused by the passage of a vehicle through their coverage area.

Road surface conditions sensors help to enhance the safety of the road and to perform maintenance programs. By employing laser and infrared technologies, they are able to check road conditions, considering parameters such as temperature and grip.

Radio-Frequency ID (RFID) sensors, which has been alresdy described at the bginning of ths paragraph, are employed in order to automatically identify achieve data of running vehicles, to facilitate smart parking and to find vehicles to allocate space for parking.

In addition to these services, which can be employed in several other applications, many other sensors are used in the provision of smart services, such as for example the **sonar technology**-based sensors installed in the smart waste management systems which will be discussed in the next section.

Special mention should be made in this context of the **measuring stations** of the Agenzia Regionale Per La Protezione Ambientale (ARPA), which play an important role in ensuring the environmental sustainability of the smart city. These measuring stations are aimed assessing the quality of the air by measuring the amount of some chemical substances in the air, namely suphur dioxide (SO2), oxides of nitrogen (NO, NO2, NOX), oxides of ammonia (NH3), particulate matter (PM10 and PM2.5), carbon monoxide (CO), ozone (O3), benzene, toluene, xylenes and black carbon. The sensors are able to detect the presence of these substances through chemical reaction-based methodologies, which includes molecular fluorescence, chemiluminescence, gravimetric method, infrared spectrophotometry, absorption of ultraviolet rays, gas chromatography and absorption of the light radiation.

4 Application Of The Proposal To The Italian Context: Qualitative Mapping Of Innovative ICT-Based Services

4.1 Individuation Of The Sample Of Medium And Large Italian Cities For The Mapping

This chapter is meant to verify the effective provision of innovative ICT-based services in a sample of cities in order to check and demonstrate the validity of the proposal presented in the third chapter of this dissertation. For this reason a qualitative mapping is performed on a sample of cities, with respect to the proposed categories and list of innovative ICT-based services. The findings of this mapping will be compared in chapter 5 with the analysis of the indicator of smartness of the ICity Rate 2017 ranking reported in the second chapter.

In this paragraph is defined the sample of cities on which the mapping has been performed.

As aforementioned, the sample of cities of the mapping has to be similar to that of ICity Rate 2017, which consists of all the Italian provincial capitals.

However, for this study it has been chosen a smaller sample: in order to avoid the difficulty of obtaining reliable data, the sample includes only the medium and large Italian provincial capitals.

Since there are currently different definitions of medium city, in this study it has been used the definition provided by the already mentioned Ranking Of European Medium-Sized Smart Cities, which defines medium-sized cities as those with more than 100.000 inhabitants.

To sum up, the sample of cities has been chosen according to the following criteria:

- cities must be Italian provincial capitals, in order to be comparable with the sample of cities of ICITY rate 2017;
- cities must be of medium and large size, in order to ensure an easier access to reliable data;
- in order to be of medium and large size, cities must have more than 100.000 inhabitants, as suggested by the TU Wien smart city ranking.

Table 48 shows the sample of cities, which consists of the list of the Italian provincial capitals with a population larger than 100.000, ranked according to their population (Istat website)[5].

[5] Istat http://dati.istat.it/Index.aspx?DataSetCode=DCIS_POPRES1, Assessed on September 2018

Ranking	City	Population	Ranking	City	Population
1	Rome	2.872.800	23	Perugia	165.683
2	Milan	1.366.180	24	Ravenna	159.115
3	Naples	966.144	25	Livorno	158.371
4	Turin	882.523	26	Cagliari	154.106
5	Palermo	668.405	27	Foggia	151.372
6	Genoa	580.097	28	Rimini	149.403
7	Bologna	389.261	29	Salerno	133.970
8	Florence	380.948	30	Ferrara	132.278
9	Bari	323.370	31	Sassari	126.769
10	Catania	311.620	32	Latina	126.470
11	Venice	261.321	33	Monza	123.598
12	Verona	257.275	34	Siracusa	121.605
13	Messina	234.293	35	Bergamo	120.923
14	Padova	210.440	36	Pescara	119.217
15	Trieste	204.338	37	Trento	117.997
16	Taranto	198.283	38	Forlì	117.863
17	Brescia	196.745	39	Vicenza	111.620
18	Parma	195.687	40	Terni	111.189
19	Prato	193.325	41	Bolzano	107.317
20	Modena	185.273	42	Novara	104.183
21	Reggio Calabria	181.447	43	Piacenza	103.082
22	Reggio Emilia	171.944	44	Ancona	100.924

Table 48: *Mapping sample: Italian provincial capitals with a population larger than 100.000. Source of information: Istat website*

4.2 Qualitative Mapping Of Medium And Large Italian Cities With Respect To The Proposed Innovative ICT-Based Services

The sample of cities used in the mapping has been explained in the previous paragraph.

The mapping is based on the list of ICT-based innovative services that has been proposed in chapter 3. The seven services categories that have been considered are: Smart Economy & E-Business Services, Smart People & E-Education Services, Smart Governance & City Administration Services, Smart Mobility Services, Smart Environment Services, Smart Living, Culture & E-Health Services, and Smart Communication & ICT-Infrastructure Services.

For each category it has been considered one or more services. The choice of the services to be included in the mapping has been performed by taking into account two main factors.

The first element that has been considered in the choice is the importance of each service. For example, the services related to the implementation of the ICT infrastructure, like the provision of ultrabroadband or fast mobile communication technologies, are very important because, as has already been said, they are the “backbone” of a smart city, enabling its development as well as the creation of other innovative services.

The second factor that has been given due consideration is the availability of information. Unfortunately, it is not always possible to find detailed information on certain services, especially the UFM services. In fact, despite the fact that the Italian Government is pushing, through Agenzia per l’Italia Digitale, for the innovation of the P.A. and for the transparency and the disclosure of open data, it is still difficult to find detailed information on certain UFM services, like the management of the sewage systems, even in the smartest cities of the northern regions.

Table 49 shows the qualitative mapping of the cities included in the sample described in the previous chapter with respect to the Innovative ICT-Based Services.

City	Smart Economy & E-Business Services	Smart People & E-Education Services	Smart Governance Services	City Administration Services	Smart Mobility Services	Smart Environment Services	Smart Living, Culture & E-Health Services	Smart Communication & ICT-Infrastructure Services
Rome	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for commuters and traffic mgmt -smart traffic mgmt systems	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (44%) and 100 Mbps (3.3%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks -5G network (in progress)
Milan	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 100 Mbps (100%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Naples	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (28%) and 100 Mbps (7.8%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Turin	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (23.6%) and 100 Mbps (15.2%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Palermo	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services (in progress) -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (71.6%) and 100 Mbps (1.9%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Genoa	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (37.7%) and 100 Mbps (4.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Bologna	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt and traffic light mgmt system	-Air quality and pollution measuring stations	-Medicines And Drugs Home Delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (30.6%) and 100 Mbps (14.1%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Florence	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt and traffic light mgmt system -Smart tickets for public transport	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (26.3%) and 100 Mbps (1.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks

City	Smart Economy & E-Business Services	Smart People & E-Education Services	Smart Governance Services	City Administration Services	Smart Mobility Services	Smart Environment Services	Smart Living, Culture & E-Health Services	Smart Communication & ICT-Infrastructure Services
Bari	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt and dedicated apps	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (71.9%) and 100 Mbps (11.3%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks -5G network (in progress)
Catania	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Journey planning -Carpooling -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (44.5%) and 100 Mbps (13.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Venice	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -LED lighting in public buildings -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart land and water traffic mgmt.	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (49.7%) and 100 Mbps (1.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Verona	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized Historical Archive (in progress)	-Free WiFi -Ultrabroadband FTTC 30 Mbps (75.9%) and 100 Mbps (11.4) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Messina	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning		-Smart street lighting (in progress)	-Car sharing -Carpooling -Journey planning	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (70%) and 100 Mbps (in progress) -4G+ and 4G networks
Padova	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning -Dedicated app for citizen participation	-Digitalization of the P. A. services	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (73.9%) and 100 Mbps (5.4%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Trieste	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized theater historical archive	-Free WiFi -Ultrabroadband FTTC 30 Mbps (44.3%) and 100 Mbps (9.2%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Taranto	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Open data from the P.A.-	Smart metering (in progress) -Smart video surveillance system	-Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (87.9%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Brescia	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning lo	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (32.2%) and 100 Mbps (52.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Parma	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (66.2%) and 100 Mbps (1.2%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks

City	Smart Economy & E-Business Services	Smart People & E-Education Services	Smart Governance Services	City Administration Services	Smart Mobility Services	Smart Environment Services	Smart Living, Culture & E-Health Services	Smart Communication & ICT-Infrastructure Services
Prato	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (39.8%) and 100 Mbps (44.3%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks -5G network (in progress)
Modena	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (45.6%) and 100 Mbps (0.8%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Reggio Calabria	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Open data from the P.A.	-Smart video surveillance system -Smart street lighting	-Bike sharing (in progress) -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (37.1%) and 100 Mbps (0.1%) -4G+ and 4G networks
Reggio Emilia	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (74.2%) and 100 Mbps (3%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Perugia	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (13.5%) and 100 Mbps (12.8%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Ravenna	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (62.7%) and 100 Mbps (0.2%) -4G+ and 4G networks
Livorno	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (77.3%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Cagliari	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services (in progress)	-Smart metering (in progress) -Smart parking -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Smart tickets for public transport -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (90.1%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Foggia	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (66.6%) and 100 Mbps (in progress) -4G+ and 4G networks

City	Smart Economy & E-Business Services	Smart People & E-Education Services	Smart Governance Services	City Administration Services	Smart Mobility Services	Smart Environment Services	Smart Living, Culture & E-Health Services	Smart Communication & ICT-Infrastructure Services
Rimini	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (88.4%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Salerno	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (79.4%) and 100 Mbps (0.2%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Ferrara	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing		-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (71.5%) and 100 Mbps (5.1%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Sassari	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (65%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Latina	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (86%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Monza	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (81.2%) and 100 Mbps (0.4%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Siracusa	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services	-Smart video surveillance system (in progress) -Smart street lighting	-Bike sharing -Carpooling -Journey planning	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (84.9%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Bergamo	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (54.8%) and 100 Mbps (1.6%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Pescara	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system (in progress) -Smart street lighting	-Bike sharing -Carpooling -Journey planning	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (81.1%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks

City	Smart Economy & E-Business Services	Smart People & E-Education Services	Smart Governance Services	City Administration Services	Smart Mobility Services	Smart Environment Services	Smart Living, Culture & E-Health Services	Smart Communication & ICT-Infrastructure Services
Trento	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car and scooter sharing -Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (29.9%) and 100 Mbps (63.8%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Forlì	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting (in progress)	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart parking -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (78.3%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Vicenza	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (47.7%) and 100 Mbps (34.4%) -4G+ and 4G networks
Terni	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart video surveillance system -Smart street lighting	-Carpooling -Journey planning -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (85.9%) and 100 Mbps (3.1%) -4G+ and 4G networks
Bolzano	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services -Open data from the P.A.	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Car sharing -Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (9.4%) and 100 Mbps (87.2%) -4G+ and 4G networks
Novara	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery	-Free WiFi -Ultrabroadband FTTC 30 Mbps (91.9%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Piacenza	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning	-Digitalization of the P. A. services	-Smart metering (in progress) -Smart video surveillance system -Smart street lighting	-Bike sharing -Carpooling -Journey planning -Smart tickets for public transport -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations	-Medicines and drugs home delivery -Digitalized museums	-Free WiFi -Ultrabroadband FTTC 30 Mbps (81.4%) and 100 Mbps (in progress) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks
Ancona	-Smart Food -E-Commerce -E-Banking -Space Sharing: Coworking & Home Sharing	-E-Learning		-Smart video surveillance system -Smart street lighting	-Carpooling -Journey planning -Smart parking -Smart sensors for traffic mgmt	-Air quality and pollution measuring stations		-Free WiFi -Ultrabroadband FTTC 30 Mbps (82.3%) and 100 Mbps (3.2%) -Ultrabroadband FTTH >1 Gbps -4G+ and 4G networks

Table 49: *Qualitative mapping of Italian provincial capitals with respect to their provision of innovative ICT-based services.*

The remaining part of this paragraph describes the services on which the mapping is based in order to show which information has been taken into consideration.

Smart food. It refers to the presence in a certain city of at least one service of food home-delivery like Just Eat, Deliveroo and many others.

E-commerce. Electronic commerce is a growing reality in Italy and nowadays e-commerce and delivery services, both B2B and B2C, can reach almost every Italian city. According to Istat (Istat website)[6], in 2017 31,9% of the population 15 years and older made online purchases while 37,7% made online payment operations. In 2017, the majority of the online purchasers were males (57,1%), most of them were resident in the North-East (58,6%) and they were between 20 and 34 years old (63%).

On the side of the supply, the Italian companies with at least 10 employees that were selling their products online in 2017 were just the 12,5%, which was still an improvement compared to the 11% of the 2016. The situation is better for the companies with more than 250 employees because the percentage grows to 34,6% (30,5 in 2016). However, in 2017, only the 8,2% of the companies that were selling their products online, made online sales that worth more than 1% of their total income (it was 7,6% in 2016). On average 81,2% of these companies sell their products online using their own apps or websites and 53,8% of these companies uses also intermediaries. Small companies (from 10 to 49 employees) is more willing to use the online sale services provided by intermediaries than big companies (more than 250 employees), in percentage is 56,8% against 34,8%.

E-banking. Currently in Italy online services of different kinds are offered by the majority of the operators, such as banks, credit institutions and investment banks.

Space sharing: coworking and home sharing. The first one alludes to the existence of at least one service offering places fully equipped to support work, that can be booked checked in real time thanks to dedicated applications. The latter refers to the availability of operators that allow people to rent and book properties on web platforms, like Airbnb, and to the presence of companies providing additional services like online self check-in and check-out, such as Keesy.

E learning. It refers to all the distance education and online reading services offered by the Universities in each city.

[6] Istat https://www.istat.it/it/archivio/commercio+elettronico, Assessed on September 2018

Digitalization of the P. A. services. This entry reports whether or not a city allows its citizens to undertake and complete bureaucratic and administrative procedures on through web portals and internet applications.

Open data from the P.A.. This entry reports whether or not local governments offer open data to its citizens, achieving the goal of transparency for the P.A. set out by the Italian Government in 2013 with the Legislative Decree 33/2013, known as "Transparency Decree".

Smart metering services. It refers to the presence and the installation of smart meters in the dwellings of the Italian cities of medium-large size. The Italian Government has recently showed a lot of interest in smart metering and in general in the implementation of smart grids. Thus, Enel, which is the most important and State-controlled manufacturer and distributor of electricity and gas in Italy, in 2017 adopted a strategy aimed to replacing the older meters with smart ones within 15 years. Similarly, many local State-controlled distributor of water all over Italy are replacing traditional meters with smart ones.

Smart video surveillance system. It refers to the adoption by the Municipalities of video-surveillance systems in order to control the territory and to fight and prevent crime. These systems are currently installed in many Italian cities, of any size, and often employ multimedia and networking technologies as well as 360 degrees wireless cameras.

Smart street lighting. This entry takes into account the presence in the medium-large sized Italian cities of public street lighting systems based on LED lamps and on devices, such as embedded smart sensors and luminous flux regulators, in order to substantially increase the efficiency of the system and decrease the consumptions.

Car sharing. It refers to the existence of at least one operator offering car sharing services in a certain city. This service typology has gained in popularity in Italy in recent years and, as to 12/31/2017, the number of the subscribers to car sharing services has exceeded one million and 29 car sharing services were active. They were provided by 11 operators, both State-controlled, like Enjoy, and private, like Car2go. Although 35 cities are served by car sharing services, most of the vehicle used for these services are still concentrated in the biggest urban centers: the 43% of the total number of vehicles is located in Milan, 24% in Rome, 15% in Turin and 8% in Florence. As showed in the following table, most of the vehicles are still using fossil fuel, although many providers offer a 100% electric vehicles fleet (Osservatorio Nazionale Sharing Mobility, 2017).

Table 50 shows all the car sharing operators in Italy, the year of activation of their service and some information concerning their fleets.

Operators	Activation Year	N Services	N Cars	Gasoline	Diesel	LPG/Methane	Electric	% Electric
Consorzio Nazionale Gestori Carsharing	2002	7	493	238	41	103	27	5%
Ubeeqo	2004	1	149	124	18	0	7	5%
E-VAI	2010	1	84	13	0	0	71	85%
Car2go	2013	4	2200	2200	0	0	0	0%
Enjoy	2013	5	2360	2360	0	0	0	0%
Carsharing Sudtirol	2013	1	34	16	16	0	2	6%
Playcar	2014	1	48	33	5	4	6	13%
Share'n'go	2015	4	1531	0	0	0	1531	100%
girACI	2015	3	128	87	6	0	35	27%
Drivenow	2016	1	500	480	0	0	20	4%
Bluetorino	2016	1	152	0	0	0	152	100%
Total			7679	3191	86	107	1851	24%

Table 50: *Car sharing operators in Italy. Source of information: (Osservatorio Nazionale Sharing Mobility, 2017).*

Scooter sharing. It shows whether or not scooter sharing services are offered in a certain city. In Italy this is a newer service typology with respect to car and bike sharing, in fact the first scooter sharing service was launched in Milan in 2015. As to 12/31/2017, only 3 operators were active in Italy, located in Rome and Milan. However, the number of subscribers has doubled from 2015 to 2017 and usage growth by 11%. In 2016 the fleet was totally composed by gasoline scooters while in 2017 electric scooters were the 68% of the fleet (Osservatorio Nazionale Sharing Mobility, 2017).

Table 51 shows all the scooter sharing operators in Italy, the city in which they operate, the service typology some information concerning their fleets.

Operators	City	Service Typology	N Scooters	Gasoline	Electric	% Electric
eCooltra	Rome	Free Floating	240	0	240	100%
Zig-zag	Rome	Free Floating	160	160	0	0%
Mimoto	Milan	Free Floating	100	0	100	100%

Table 51: *Scooter sharing operators in Italy. Source of information: (Osservatorio Nazionale Sharing Mobility, 2017).*

Bike sharing. This entry indicates the existence of at least one operator that offers bike sharing services in a certain city. This service typology is very popular in the Italian cities, being available in 265 Municipalities as to 2017. In addition, between 2016 and 2017 it showed an 147% growth, thanks mostly to the fact that three new free-floating operators, Mobike, Ofo and Obike entered the market in that period. The majority of these services, as to 12/31/2017, were located in the cities of Northern Regions, followed by the South and the Center, respectively 59%, 28% and 13%. However most of the bicycles were concentrated in four cities: Milan (44% of the bicycles), Turin (13%), Florence (8%) and Rome (5%). The total number of shared bicycles was 39.500 and the number of bike sharing services installed was 286, developed by 8 operators (Osservatorio Nazionale Sharing Mobility, 2017).

Table 52 shows all the bike sharing operators in Italy, the service typology and some information concerning their fleets.

Operators	Service Typology	N Services Installed	N Bicycles	N Pedal-Assisted Bicycles	N Stations	Year Active in Italy
Bicincittà	Station Based	121	7.056	12%	1.535	2004
Clear Channel	Station Based	2	4.900	20%	305	2008
By Bike of Ecologica	Station Based	15	516	9%	82	2008
Ecospazio of LOGISS	Station Based	89	1.034	51%	135	2010
TMR	Station Based	16	659	34%	73	2014
OfO	Free Floating	2	4.900	0%	-	2017
Mobike	Free Floating	5	12.940	0%	-	2017
Obike	Free Floating	2	5.000	0%	-	2017

Table 52: *Bike sharing operators in Italy. Source of information: (Osservatorio Nazionale Sharing Mobility, 2017).*

Carpooling. It refers to the availability of services consisting in the sharing of car journeys in a certain city. The extra-urban carpooling, the one that covers medium-long distances, is still the most successful in Italy, with BlaBlaCar that reached 2,5 millions subscribers in 2017. However, the urban carpooling, both for individuals and companies, had a rapid growth between 2015 and 2017, from 72 thousands to 265 thousands subscribers

respectively. In Italy 7 operators are currently active and the table below refers to those operating in the urban context (Osservatorio Nazionale Sharing Mobility, 2017).
Table 53 shows all the carpooling operators in Italy, the service typology, the areas in which they operate and the year of activation of their service.

Operators	Service Typology	Territorial Dimension	Year Active
Clacsoon	Urban	National	2015
BlaBlaCar	Extra-urban	National	2012
Zergo	Urban	Milan and Turin	2015
BePooler	Mixed	Milan, Rome and Turin	2017
Scooterino	Urban	Rome	2015
Jojob	Mixed	National	2014
Up2go	Urban	National	2015

Table 53: *Carpooling operators in Italy. Source of information: (Osservatorio Nazionale Sharing Mobility, 2017).*

Journey planning. It reveals the presence of journey or trip planners in the medium and large Italian cities, which have been considered. Moviit is by far the most widespread operator and it is quicky incrementing the number of cities in which it operates (Osservatorio Nazionale Sharing Mobility, 2017).
Table 54 shows all the journey planning operators in Italy, their territorial dimension, the number of cities in which they operate, the year of the activation of the service and their offer.

Operators	Territorial Dimension	N Cities	Aggregated Services	Year Active
Urbi	Urban	5	Car Sharing, Bike Sharing, Scooter Sharing, Taxi, Public Transport	2016
Free2Move	Urban	4	Car Sharing, Bike Sharing, Scooter Sharing	2017
Moovit	Urban	34	Public Transport	2013

Table 54: *Journey planning operators in Italy. Source of information: (Osservatorio Nazionale Sharing Mobility, 2017).*

Smart parking. It indicates whether or not a city is provided with services that help users to find parking lots or to manage the parking fees and procedures.

Smart tickets for public transport. This entry shows which cities offer ICT-based integrated tickets and support electronic payment for them. For example, in addition to electronic payment ATM, the company responsible for public transportation in Milan, recently launched an innovative system that allows users to use their VISAs/Mastercards or their smartphones and smartwatches as contactless tickets. This smart system calculates, at the end of the day, the sum to be paid, applying automatically the cheapest fare.

Smart sensors for traffic management. It refers to the presence of services aimed at regulating the traffic, avoiding congestions and even informing the citizens about the situation of the transportation network in real time. Many Italian cities adopt this kind of smart systems, which may employ not only the in-road sensors described in chapter 3, but also the cameras of the smart video surveillance systems.

Medicines and drugs home delivery. It indicates the presence in a city of operators that offer services of home delivery of drugs and medicines. Some of the most important operators are FarExpress, Pharmatruck and Pharmap.

Digitalized museums / historical archive. It has been taken into account the museums and the historical archives which provides virtual online tours of museums or digitalized documentation available online.

Free WiFi. It refers to the presence of free public wifi hotspots in the city.

Ultrabroadband. It refers to the FTTC and FTTH technologies. The objective of the Italian Government, signed in 2015 in accordance with the Europe 2020, is to reach certain population coverage levels of the 30 Mbps and 100 Mbps ultrabroadband, which are respectively the 100% and the 85%. The medium-large Italian cities are already reached by the broadband, such as the ADSL. Currently, the installation of ultrabroadband is in progress in the all the Italian cities that have been considered. The data employed refers to the beginning of 2018. Here it is reported the coverage of the FTTC (fiber-to-the-cabinet) and of the FTTH (fiber-to-the-home) ultrabroadband. The Ministry for the Economic Development's website takes into account two FTTC ultrabroadband: the one with a speed transmission of 30 Mbps and the one with a speed transmission of 100 Mbps. According to the Ministry for the Economic Development, from which the data come from, the 99% of the households located in the medium-large cities will be reached by the FTTC ultrabroadband by the year 2020. In addition, a considerable part of the 30 Mbps connections will be gradually replaced with 100 Mbps connections (Ministero dello Sviluppo Economico website)[7].

[7] Ministero dello Sviluppo Economico http://bandaultralarga.italia.it/mappa-bul/, Assessed on September 2018

The FTTH ultrabroadband, which has already reached many Italian cities in the past years thanks to Fastweb, is currently increasing its level of coverage with Open Fiber, a company controlled by ENEL (Open Fiber website[8]; Fastweb website[9]).

4G, 4G+ and 5G. It refers to the cellular mobile technologies that are provided in each city. The table focuses mostly on the fourth-generation technologies because the third one (and of course the previous one) has been almost completely replaced by it, at least in the medium-large cities. The 5G is currently under development and in Italy the initial tests will begin in 2019 in five pilot cities: Milan, Prato, Bari, Matera and L'Aquila. The latter two are small cities and thus are not considered in the table (NPERF website)[10] .

[8] Open Fiber https://openfiber.it/it/fibra-ottica/coperturaftth, Assessed on September 2018
[9] Fastweb https://www.fastweb.it/adsl-fibra-ottica/rete-fibra-ottica/, Assessed on September 2018
[10] NPERF https://www.nperf.com/en/map/IT/-/-/signal/?ll=32.430791081652565&lg=9.052734375000001 &zoom=4, Assessed on September 2018

5 Proposal Of An Integration Of The Indicators Of Smartness Employed By The Smart City Rankings With Respect To Innovative ICT-Based Services

5.1 Comparison Between The Mapping Findings And The Smart City Ranking Indicators

This paragraph is meant to compare the findings of the qualitative mapping of the previous chapter with the analysis of the indicators of smartness of the ICity Rate 2007 performed the second chapter. The purpose of the comparison is to highlight the need for an integration of the aforementioned ranking, consisting of new indicators of smartness related to the provision of smart services.

Here are reported the findings of the qualitative mapping of Italian provincial capitals with respect to their provision of innovative ICT-based services:

- the list of services proposed in chapter 3 has proved to be effective, since it enabled to individuate and map those services in the sample of cities;
- *even if the mapping is a qualitative analysis and not a quantitative one*, it highlights that the medium and large provincial capitals are provided with innovative ICT-based services which belong to all the classes of services defined and proposed in chapter 3;
- the higher level of smartness of the Northern cities appears to be confirmed by the mapping. However, the gap between the northern and the southern and central cities seems to be less relevant;
- a variety of heterogenous services exists in some of the cities examined, not only in the smart cities of the north-east and of Emilia-Romagna (ranked as the smartest according to ICity Rate 2017);
- in particular, the Government is making substantial investment to encourage development of the ICT infrastructure and of smart grids and smart metering across the country in order to decrease the gap;
- for example, the city of Bari is ranked 68th by ICity Rate 2017 but it appears to be provided with many smart services, in particular for what concern the provision of Smart Communication & ICT-Infrastructure Services.

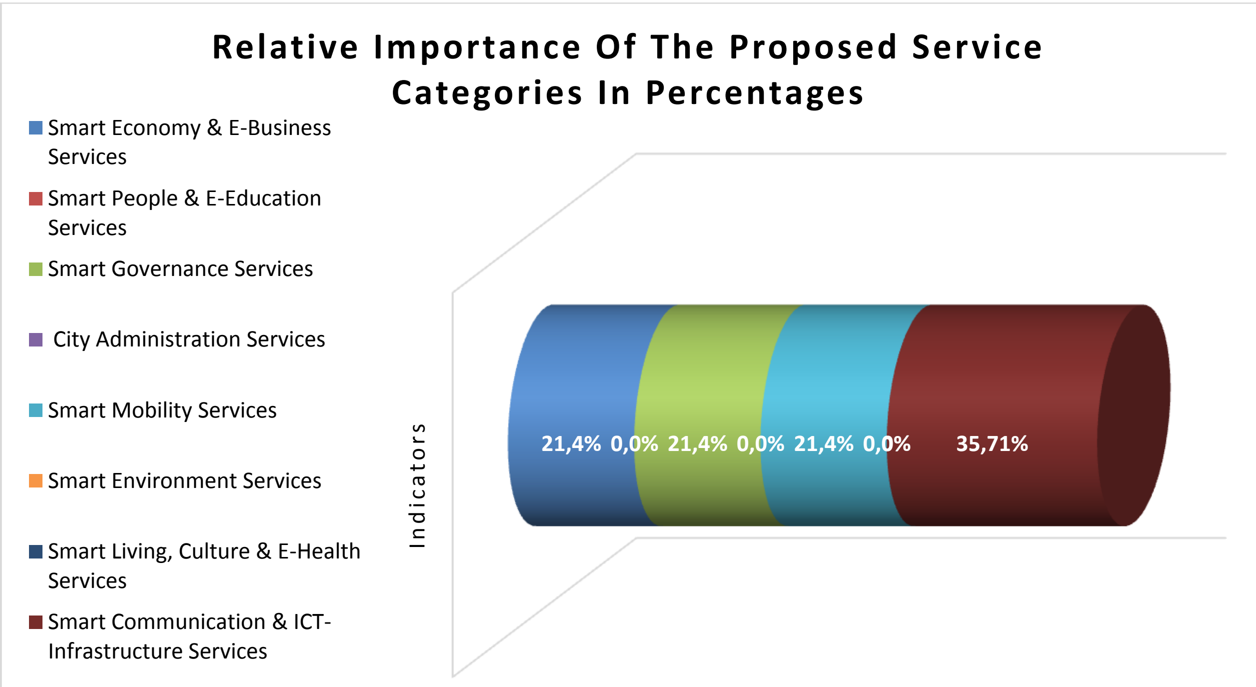
The indicators of the ICity Rate 2017 gives more importance to social and economic factors than to the provision of innovative ICT-based services, as already discussed in chapter 2.

	Indicator	Methodology / Description	Source
Smart Economy & E-Business Services	E-Commerce	Companies that sold or bought products online during the previous year	Istat
	Home Banking Diffusion	Number of clients of home and corporate banking services	Forum PA calculations on data coming from Bank of Italy and Istat
	Co-working	Coworking services percentage in a city of the total in Italy.	Data collected directly by Forum PA
Smart People & E-Education Services	---	---	---
Smart Governance Services	Open Data	Indicator based on the number of dataset available, the presence of a dedicated web page, feedback/demand analysis tools, presence of an application	Data collected directly by Forum PA
	Online Services	Good fruition level (3 or 4) of online service as a percentage of the total number of online services	Istat
	Digital Growth	Composite indicator that takes into account the number of services that accept SPID and CIE and the number of administrations that adopt Pago PA and Fattura PA	Forum PA calculations on data coming from AGID and Ministry of the Interior
City Administration Services	---	---	---
Smart Mobility Services	Carsharing	Number of vehicles, employed in car sharing services, available per 1000 inhabitants	Forum PA calculations on data coming from Osservatorio Sharing Mobility
	Bike Sharing	Number of bicycles, employed in bike sharing services, available per 1000 inhabitants	Forum PA calculations on data coming from Osservatorio Sharing Mobility
	Electric Mobility	Number of electric vehicles charging stations per square Km	Forum PA calculations on data coming from Enel Drive, A2A, Hera and other operators
Smart Environment Services	---	---	---
Smart Living, Culture & E-Health Services	---	---	---
Smart Communication & ICT-Infrastructure Services	Public Wi-Fi	Number of free WiFi access point per 100.000 inhabitants	Istat
	Broadband 30MBps	Percentage of dwellings in a city reached by a 30MBps connection	Infratel
	Broadband 100MBps	Percentage of dwellings in a city reached by a 100MBps connection	Infratel
	Connectivity In Residential Areas	Average download speed (Mbps) for ADSL users in a city	Sostariffe.it
	Ultra-Wideband Diffusion	Number of subscriptions to ultrabroadband as a percentage of the population of a city	Istat calculations on data coming from AGCOM

Table 55: *ICity Rate 2017 indicators related to smart services according to proposed services categories: methodologies and sources of data. Adapted from: ICity Rate 2017 (FORUM PA, 2017).*

The ICity Rate 2017 indicators related to the smart services are presented in Table 55 with the methodologies and sources from which the data have been extracted. The Table reports the indicators classified according to the smart service categories proposed in the third chapter.

Graph 3 summarizes the result of the previous table, showing the relative importance that the ICity Rate 2017 gives to each service category expressed in percentages.



Graph 3: *Relative importance of the proposed service categories in percentages. Adapted from: ICity Rate 2017 (FORUM PA, 2017).*

Form Table 54 and Graph 3 it can be seen that:

- Smart People & E-Education Services, Smart Governance Services, Smart Environment Services, Smart Living, Culture & E-Health Services are not covered by any service indicator. For example:
    - there are no indicators concerning e-education or e-leaning;
    - there are no indicators concerning resource management, smart metering, smart grids, smart security etc.;
    - there are no indicators concerning e-health.
- on the contrary, in the qualitative mapping presented in the fourth chapter these service categories are covered by many services.

- the remaining service categories are not enough either covered by smart service-related indicators. In particular many innovative services which are very common or very important today (concerning topics like, for instance, sustainability) are not taken into account. For example:
    - there is no attention to the smart services offered by the public transport system;
    - there is no mention of indicators concerning new e-businesses, such as smart food.

As already discussed in chapter 2, smart city rankings, regardless the aim for which they have been created, can be very powerful tools, able to influence many important factors.

They may be able to draw the attention of the mass media and to help local governments to develop strategies and to promote transparency or, on the contrary, they may promote stereotypes and rivalry among cities.

However, the fact that rankings, by internationally promoting the image of a city, may have big resonance on a global level, transforms them into tools able to influence the market.

Besides public investment for the development, rankings, by influencing the market, may be able to boost the real estate market and to attract property investors and new entrepreneurs.

For example, a ranking that hold in high regard the provision of ICT-based services and of the ICT infrastructure, can be an important tool for attracting new entrepreneurs of businesses enabled by the ICTs.

For all the reasons exposed in this paragraph, the list of indicators of the ICity Ranking 2017 appears to be not adequately detailed and complete for what concerns the indicators that measure the provision of innovative ICT-based services in a city.

Thus, in the next paragraph a more detailed list of such indicators is proposed.

5.2 Proposal Of A List Of Indicators That Considers The Provision Of Innovative ICT-Based Services In The Smart City Context

The aim of this paragraph is to propose a list of indicators which measures the provision of ICT-based innovative services that are offered in smart cities. The list of indicators is intended to ingrate smart city rankings, and in particular the ICity Rate 2017, in order to increase the relative importance of the smart services' offer in each ranking.

The indicators are meant to measure the provision of services in smart cities and, thus, they are based on the list of innovative ICT-based services which has been suggested in the third chapter.

The proposed list is made up of different types of indicators, due to the heterogeneity of the typologies of services examined and due to the fact that it is not always possible to find reliable data. In particular, the indicators proposed in this list can be classified as quantitative and "boolean".

Quantitative indicators are numeric and they can be expressed in many ways like numbers, percentages, monetary values, ratios, decimals and many others. In this dissertation most of the quantitative indicators have been expressed in relation to the population or to the area of each city.

The term "boolean" indicator is referred here to those indicators that can have only one of two possible values. For example, the indicator "5G trials" cannot be expressed as a number or as percentage, it can only be expressed through a Boolean variable.

The objective of this dissertation is not to implement this list of indicators in the ICity Rate 2017, but it is to address the problem and to steer the research towards the inclusion of more smart service-oriented indicators in smart city rankings. For this reason, for each indicator it has been reported the possible sources for data extraction, in order to steer future researches on the right track. While in some cases it has been possible to directly verify the reliability of the sources, in few cases this was not possible because the access to some data is not open. Some data, in fact, are publicly available upon payment, while others can be accessed only by companies or institutions, such as Forum PA. However, all the proposed indicators can be built employing existing data, which can be retrieved from the sources for data extraction reported in this paragraph. Thus, the aim of the proposed sources is to indicate where to search for data, as well as to demonstrate the feasibility of the indicators, due to the possibility of retrieving all the data.

Table 56 shows the proposed list of 39 indicators of smartness with the methodologies which have been employed to obtain each indicator and the possible sources for data extraction. The indicators are classified according to the service categories proposed in chapter 3.

	Indicator	Methodology / Description	Possible Sources For Data Extraction
Smart Economy & E-Business Services	Food home delivery penetration	Number of restaurants that offer the service through dedicated app per 1000 inhabitants	-number of restaurants provided by service providers' websites -Population provided by Istat
	Food home delivery coverage	Percentage of the Municipality territory covered by the service	-covered areas provided by service providers
	E-commerce penetration	Number of companies that sold or bought products online during the previous year as a percentage of the total number of companies in the city	-Camera di Commercio and Istat
	E-banking penetration	Number of clients of home and corporate banking services or mobile applications users per 1000 inhabitants	-Osservatorio Mobile Banking (ABI Lab and School of Management del Politecnico di Milano) -Bank of Italy -Istat
	Co-working	Coworking services spaces (sqm) in the city per 1000 inhabitants	-Forum PA
	Home sharing	Average monthly number of dwellings available for renting on web platform and dedicated applications as a percentage of the total number of dwellings in the city	-Service providers web sites and platforms (like Airbnb) -Number of dwelling provided by Istat and Municipalities
Smart People & E-Education Services	E-learning	Number of online learning platform and online classes provided by the universities of a city	-Universities web sites and platforms
Smart Governance Services	Digitalization of the P.A. procedures	Number of procedures that can be undertaken and totally completed online as a percentage of the total of the procedures in a city	-Web sites and web portals of the Municipalities and of the P.A.
	Digitalization of the P.A. payments	Number of public entities and administrations in a city that employ pagoPA as a percentage of the total	-AGID -Web sites and web portals of the Municipalities and of the P.A.
	Digitalization of the P.A. authentications	Number of public entities and administrations in a city that use SPID as a percentage of the total	-AGID -Web sites and web portals of the Municipalities and of the P.A.
	Open data access	It indicates whether or not a Municipality enable free access to updated open data	-Web sites and web portals of the Municipalities
City Administration Services	Smart metering of electricity	Percentage of smart electricity meters of the total of electricity meters in a city	-public utilities that provide the services (Enel, A2A etc)
	Smart metering of gas	Percentage of smart gas meters of the total of gas meters in a city	-public utilities that provide the services
	Smart metering of water	Percentage of smart water meters of the total of water meters in a city	-public utilities that provide the services
	Number of smart security cameras	Number of surveillance smart cameras per 1000 inhabitants	-number of cameras provided by Municipalities -population provided by Istat
	Coverage of smart security cameras	Percentage of city territory covered by surveillance smart cameras	-Municipalities
	LED public illumination	Number of LED street lamps in a city as a percentage of the total street lamps in the public lighting system	-Municipalities -public utilities that provide the services
	Smart waste disposal	Number of smart trashcans in a city as a percentage of the total	-public utilities that provide the services -Municipalities

Smart Mobility Services	Car and scooter sharing subscriptions	Number of subscriptions to car and scooter sharing services in a city per 1000 inhabitants	-number of subscriptions supplied by service providers and Osservatorio Sharing Mobility -population supplied by Istat
	Bike sharing subscriptions	Number of subscriptions to bike sharing services in a city per 1000 inhabitants	-number of subscriptions supplied by service providers and Osservatorio Sharing Mobility -population supplied by Istat
	Automated public transport (railways)	Km of subway lines fully automated (GoA 4) as a percentage of the total	-Municipalities and public utilities service providers
	Smart traffic monitoring	Percentage of the Municipality territory covered by smart traffic monitoring systems	-Municipalities
	Smart parking	Number of the smart parking as a percentage of the total parking areas in a city	-number of smart parking given by service providers -number of parking areas provided by Municipalities
	Carpooling	Average monthly number of journeys offered within the city or that have the city as starting point or as destination	-carpooling operators
	Journey planners	Percentage of journey planners with booking or payment options with respect to the total of journey planners in a city	-journey planner operators -Municipalities and public utilities
	Smart public transport	It indicates whether or not the public transport system employs smart integrated ticked, travel cards or mobile applications with booking and payment options	-Municipalities and public utilities
Smart Environment Services	Measuring stations open data availability	It indicates whether or not updated data concerning a city are available online in real time to the citizens	-Municipalities and public utilities websites and web portals -ARPA
Smart Living, Culture & E-Health Services	Digitalization of museums	Number of museums offering virtual online tours as a percentage of the total number of museums in a city.	-Municipalities -museums websites and web portals -Ministero per i beni e le attività culturali website
	Digitalization of historical archive collections	Number of the historical archive collections digitalized and available on web sites and web portals as a percentage of the total historical archive collections in a city	-Municipalities -archives -website of the Ministry of Cultural Heritage and Activities
	Medicines home delivery services	Number of medicines home delivery services in a city per 1000 inhabitants	-web sites and web portals of service providers -Istat
	Medicines home delivery services coverage	Percentage of the Municipality territory covered by these services	-percentage of the territory covered given by service providers

Smart Communication & ICT-Infrastructure Services	Free public WiFi	Number of free WiFi access point per 1000 inhabitants	-websites of Municipalities -dedicated apps
	Ultrabroadband FTTC 30 Mbps coverage	Percentage of building units reached by FTTC 30 Mbps services with respect to the total building units of a city	-bandaultralarga.italia.it, official data of the Ministry of Economic Development
	Ultrabroadband FTTC 100 Mbps coverage	Percentage of building units reached by FTTC 100 Mbps services with respect to the total building units of a city	-bandaultralarga.italia.it, official data of the Ministry of Economic Development
	Ultrabroadband FTTH >1 Gbps coverage	Percentage of building units reached by FTTH >1 Gbps services with respect to the total building units of a city	-service providers (mainly Open Fiber, Fastweb and Colt) -AGCOM -Municipalities
	Download speed of the fixed internet connection	Average download speed (Mbps) of fixed connections in a city	-Sostariffe.it website -Ookla
	4G LTE and 4G LTE Advanced coverage	Areas covered by 4G LTE and 4G LTE Advanced services as a percentage of the total city area	-www.nperf.com website -www.misurainternetmobile.it by AGCOM -Municipalities
	5G trials	It indicates whether or not a city is involved in 5G trials	-Municipalities - Ministry of Economic Development website
	Download speed of mobile internet connections	Average download speed (Mbps) of mobile connections in a city	-www.misurainternetmobile.it by AGCOM -Ookla

Table 56: *Proposed list of smart service-related indicators according to proposed service categories: methodologies and sources for data extraction.*

For completeness, it is useful to report some considerations about the indicators reported in Table 55 and, in particular, concerning the methodologies of certain specific indicators:

- all the indicators have been created looking at the list of innovative ICT-based services in the smart city context, proposed in this dissertation, chapter 3;
- some indicators measure directly the provision of smart services in a city;
- sometimes it is impossible or not useful to directly measure the provision of services in a certain city. E-commerce or e-banking services, for instance, are offered evenly across the territory and service providers can be located in other cities or Countries. Thus, in such cases, indicators show the effective use of the services, which describes roughly the penetration of such services in a certain city;
- car sharing, scooter sharing and bike sharing indicators are not able to directly measure the importance of these services in each city. In fact, the indicators relate the number of

subscriptions and the number of cars with the city population. However, the users of sharing services do not live necessary in the city in which the services are provided. Thus, both the indicators proposed in this paragraph and those employed by ICity rate 2017 are meant to roughly estimate the penetration of these services in a city. More appropriate and precise indicators, although impossible to be calculated, could be:

- number of the vehicles of the fleet of the sharing service as a percent of average of the total number of vehicles circulating in the city;
- number of kilometres travelled daily by the fleet of the sharing service as a percentage of the total number of kilometres travelled daily by vehicles in a city.

However, it is impossible to calculate the two previous indicators due to the lack of data. In particular, it is almost impossible to find reliable data concerning the average of the total number of vehicles circulating in the city or the total number of kilometres travelled daily by vehicles in a city;

- concerning ultrabroadband services, the term building units designates all the building units of a city, regardless their intended use. Thus, these indicators include both ultrabroadband services for citizens and for companies.

Conclusions

The two main objectives of this study, as already stated in the abstract, were: 1) to propose service categories aimed at facilitating the development of systems of indicators of smart city rankings focused on the provision of innovative ICT-based services, 2) to integrate the smart city rankings examined by proposing a list of indicators of smartness based on the provision of these services.

The first part of this dissertation was intended to analyze of the current scenario of both the smart cities and the ICTs. At the very beginning, the concept of smart city was defined through a rich literary review so as to pinpoint the importance of ICTs as facilitators of smartness. In particular, the Internet of Things was described in detail along with the related concept of Big Data and it was recognized as the most important enabler of smart urban services. An overview of the Urban Facility Management services was provided to the reader. The analysis of the current scenario of the smart cities was completed by a short overview on the current urban situation in Italy and by the introduction of a tool able to assess the smartness of a city, the smart city ranking. Four influential smart city rankings were reported and described together with their systems of indicators. Then, they were compared on the basis of their indicators of smartness in order to choose the best ranking in terms of the relative importance given to the provision of innovative ICT-based services.

The second part of this study addressed the two aforementioned objectives by illustrating two proposals. Different examples of existing categories of smart services were reported and compared in order to propose a new categorization: many service classifications have been produced over the years, each with their own categories, but none of them was specifically designed to help identify smart services and to facilitate the creation of a system of indicators of smartness focused on the provision of innovative ICT-based services. In accordance with the suggested categories, a list of these smart services, both UFM and not-UFM, was proposed and the most important among them were described through examples and case studies.

In order to verify the effective provision of services and therefore the validity of the proposal, a qualitative mapping was performed on a sample of cities similar to that of the aforementioned best ranking, with respect to the proposed categories and list of innovative

ICT-based services. Then, an analysis of the indicators of smartness of that ranking was presented together with the findings of the qualitative mapping, highlighting the need for an integration of the system of indicators, to make it more smart service-related. Thus, the last section illustrated the proposal of a list of indicators of smartness which measures the provision of ICT-based innovative services that are offered in smart cities.

The strength of this dissertation relies on the completeness and consistency of its methodology, in fact, through the use of a rich literary review, comparisons and real case studies, it was able to illustrate the legitimacy and the necessity of its proposals as well as to justify them.

On the contrary, the weaknesses of this study depend on its limited field of research compared to the complexity and the depth of the topics. Many publications exist concerning topics such as the ICT, IoT and smart city concept definition. Plus, ICTs have very wide-ranging fields of application and, consequently, the situation is very dynamic, with a huge number of smart services currently available or under development.
The context of the smart city rankings is also complex and dynamic, several rankings have been published, each with their own targets and scope, some publicly available and based on high-quality data sources, some not. Thus, only four smart city rankings, and consequently only four systems of indicators, have been considered out of the many smart city rankings and indicators that have been developed.

In conclusion, this study, despite being a partial analysis due to the limitations that have been highlighted, is aimed at being a useful contribution, if not a starting point, for future researches and publications in that direction.
In fact, the objective was not to implement a list of indicators or a service categorization on the examined smart city rankings. On the contrary, the goal of this dissertation was to address the problem and to attract the attention of researchers in the field, steering the future research towards the inclusion of more smart service-oriented indicators in smart city rankings.
In other words, this study is intended to raise awareness on the importance of smart city rankings which valorise the provision of innovative ICT-based services, because they are becoming more and more key elements in the promotion of the international image of the cities, potentially enabling them to gain the attention of the Government and of the market.

For this reason, besides enabling the achievement of public investments for the development, smart city rankings, by influencing the market, may be able to boost the real estate market and to attract property investors and new entrepreneurs.

What this dissertation hopes to accomplish is that the developers of smart city rankings will decide in the future to increase, in their rankings, the relative importance and the number of indicators of smartness directly related to the provision of innovative ICT-based services.

However, it is important to point out once again that rankings are made with specific purposes, taking into account different factors such as the target audience. Nevertheless, the final recommendation is that smart city rankings in future will be able to assess the level of smartness valorising and paying greater attention to the provision of urban smart services in cities, maybe even by employing the indicators and the services categories proposed in this study.

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