Interdepartmental Programme of Postgraduate Studies in Information Systems

Master Thesis

# *“Internet of Things in Smart Cities”*

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Thessaloniki, September 2020

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**INTRODUCTION**

**Statement of the problem**

The rapid expansion and advance of Internet of Things (IoT) allowed the dream of smart cities to become a reality (Hui et al., 2017; Urbieta et al., 2017; Kim et al., 2017). In fact, IoT is an extension of the Internet, which gives people, objects, and information systems the ability to connect with each other (Rashid et al., 2017). As González García et al. (2017, p. 301) claim, "The Internet of Things allows creating huge or small networks in order to obtain a collective intelligence through the processing of objects' information". Based on this connectivity, the concept of 'Smart City' refers to a model of sustainable urban development, allowing better quality of life, respect and protection of the environment, as well as better interaction between citizens and between citizens and the government (Ben Sta, 2017; Kim et al., 2017).

Due to the various advantages that IoT offers to a smart city, several countries have followed this paradigm in the development of metropolitan areas, where emphasis has been given to peoples' mobility, energy, environment, and transportation. Some examples include the following: a) LED street lighting n Los Angeles, Boston, Madrid, Edmonton; b) climate and environmental issues existing in the regions across the border between Denmark and Sweden; c) smart energy kits in Taiwan; d) smart roads in Bristol; e) automating pricing depending on traffic in Santiago; f) traffic and emergency monitoring in Rio de Janeiro; g) smart energy and mobility themes in Amsterdam, h) sensors in high-traffic roads in Padova.

What should be mentioned, however, is that IoT is not a panacea, since there are still some improvements that should be made, in terms for example of protocols and security (González García et al., 2017), privacy (Kim et al., 2017), as well as peoples' access to the technologies of a smart city and financial sustainability (Urbieta et al., 2017). Nevertheless, it can be argued that this technology offers a number of advantages, through the interconnection, and for this reason it should be further examined and analyzed.

**Aim of the research**

The aim of the present research is to examine how IoT can be used in order to support the concept of smart city, based on current projects that already exist and, on a questionnaire, designed by me, in order to examine the possibility of developing more smart parking applications. The objectives of this research are the following:

a) To present an overview of the IoT
b) To examine the smart city services offered through existing examples
c) To focus on mobility, energy and transportation themes in smart cities based on the example of specific metropolitan areas
d) To examine users' perceptions and behaviour of using Smart Parking Systems

**Interest in the conduct of the research and expected outcomes**

The concept of Smart City based on the advantages and the possibilities offered by the IoT is an alternative, sustainable model for the development of urban / metropolitan areas (Ben Sta, 2017). As a result, there is a great interest in this developmental model, since it can result in better life quality and environmental-friendly ways of transportation using ICTs. For instance, IoT in the case of smart cities offers numerous advantages to people and the environment, such as improvement of accessibility on behalf of people with disabilities (Rashid et al., 2017), better healthcare (Farahani et al., 2018), and increased security (González García et al., 2017). Since there are various smart city services, this research will focus upon mobility, energy and transportation applications.

Overall, it is of great interest and importance to examine how exactly this technology can be used in favor of the people and the environment, based on real-life cases, within the framework of the literature review, exploiting the international bibliography (books and academic articles) regarding IoT and reports regarding cases of smart cities. Besides, IoT and the associated technologies are still in an initial phase (Díaz-Díaz et al., 2017), which means that there is a need for the analysis, comparison and the evaluation of the practical implementation of these technologies. As a result, through the analysis of several examples of cities that have implemented applications of smart solutions in the case of transportation, we can draw useful conclusions about the following issues: a) how can IoT improve peoples' life; b) what are the obstacles that may hinder the evolution of a smart city; c) whether the proposed solutions entail considerable risks and how they come be overcome.

**Structure**

The structure of this assignment is as follows. The first chapter deals with the concept of IoT. This chapter includes an overview of the IoT, its enabling technologies, as well as the challenges and risks entailed in smart city applications. The second chapter analyses smart city applications. At first, there is a presentation of the several smart city services offered based on IoT, where the second part place emphasis upon themes of mobility, energy and transportation, which is the main focus of this research. The first chapter discusses some of the main Smart Parking Systems in Greece and abroad. The next chapter presents the methodology of the research conducted, while the fifth chapter presents the results of the survey. The last chapter summarizes the main findings of the research, and make suggestions for further research based on the findings and the limitations of the present study.

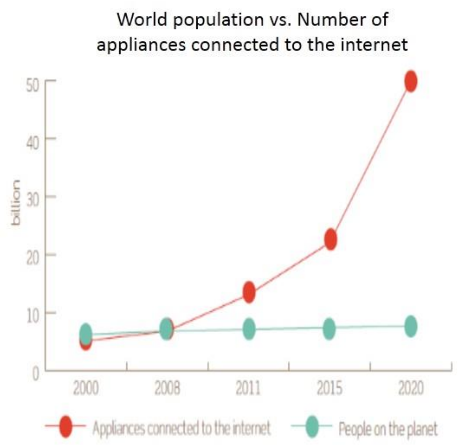
# CHAPTER 1. INTERNET OF THINGS

## 1.1 Overview of the IoT

The term 'Internet of Things' was appeared for the first time in 1999 in an article presenting report on RFID in Procter and Gamble. The idea of the automatic data collection using both RFID technology and detection technology, along with the continuous development of Wireless Sensor Networks (WSNs), M2M, Artificial Intelligence (AI) and Semantic Technologies, allowed the development of IoT. In fact, IoT is regarded as an extension of the existing Internet, where Human-to-People interaction (H2H) dominates in the daily communication of the network. Familiar today H2H examples are text messages, voice and video teleconferencing, as well as social networking. Human-machine interaction (H2M) has become another important part of communication over the Internet when machines become smarter with AI. A smart machine or a smart computer can customize the content for a dynamic website and show it to a specific user according to its browsing history. IoT is an idea to connect objects to the Internet and the Thing-to-Thing or M2M interaction is the basic technology of IoT (Hui et al., 2017).

Box 1. The Internet of Things

In 2008, history was made as the number of appliances connected to the internet surpassed the number of people on the planet for the first time ever, foreshadowing a future where it is not only the people on this planet which are connected, but also the things see. The ever increasing number of digital devices and appliances being connected to the internet do not only allow an increasing flow of information between man and machine; the devices and appliances themselves are becoming interconnected and able to communicate without the interference of people. Referred to as the 'Internet of Things', this system of technology has almost infinite possibilities when it comes to developing sustainable solutions for cities. A recent report from the Alexandra Institute, which was produced by a number of experts in the field of technology and urban development, describes 60 different scenarios ranging from intelligent waste treatment, city planning or transport to emergency response and healthcare where the Internet of Things might help to create more efficient solutions. One example is the intelligent waste bin, which uses ICT to measure its contents. This allows it to inform the waste collectors when it is nearly full, thus optimizing the waste collection routes of the city. Furthermore, it provides information to the consumers about the environmental footprint of their waste.




Source: Copenhagen Cleantech Cluster, 2012, p. 7

The following figure depicts the objectives of IoT. These objectives are Anything, Anyone, Anytime, Anyplace, Any service and any network and in order to achieve these objectives one needs to address issues referring to Convergence, Content, Collections (Repositories), Computing, Communication, and Connectivity.

Figure 1. Objectives of IoT


Source: Adisesha et al., 2017, p. 139

Therefore, IoT allows the interconnection of physical and virtual things. These things may be objects of the natural world or information of the virtual world. This interface can be done at any time and from anywhere, and between H2H, M2M and H2M. However, many heterogeneous things make up the IoT. The most important are Wireless Sensor Networks (WSN), which are the core of the IOT. A WSN interconnects sensors in order to acquire data with a server or special system to process and perhaps automate tasks in one place. Other components are actuators, which allow actions such as engines, fans, machines, and so on. Another type of network is the fusion between a WSN and actuators, known as the Wireless Sensor and Actuator Network (WSAN). Besides, Smart Objects are other important elements because they can act, they can feel because they usually have sensors and are smart in order to be able to process information or data and perform actions. All of these items can be connected to the Internet. Therefore, IoT is the interconnection of heterogeneous objects to each other over the Internet. Thus, the aim of IoT is to interconnect the whole world by creating different smart positions to automate, improve and facilitate the daily lives of citizens (González García et al., 2017; Farahani et al., 2018). In general, all the above are included in the term 'Internet of Everything' (IoE), which brings together people, process, data and things, as explained in the table below.

Table 1. Levels of interconnection within IoT

| | |
|---|---|
| People | In IoE, people will be able to connect to the Internet in innumerable ways. Today, most people connect to the Internet through their use of devices (such as PCs, tablets, TVs, and smartphones) and social networks (such as Facebook, Twitter, LinkedIn, and Pinterest). As the Internet evolves toward IoE, we will be connected in more relevant and valuable ways. For example, in the future, people will be able to swallow a pill that senses and reports the health of their digestive tract to a doctor over a secure Internet connection. In addition, sensors placed on the skin or sewn into clothing will provide information about a person's vital signs. According to Gartner, people themselves will become nodes on the Internet, with both static information and a constantly emitting activity system |
| **Data.** | With IoT, devices typically gather data and stream it over the Internet to a central source, where it is analyzed and processed. As the capabilities of things connected to the Internet continue to advance, they will become more intelligent by combining data into more useful information. Rather than just reporting raw data, connected things will soon send higher-level information back to machines, computers, and people for further evaluation and decision making. This transformation from data to information in IoE is important because it will allow us to make faster, more intelligent decisions, as well as control our environment more effectively |
| **Things** | This group is made up of physical items such as sensors, consumer devices, and enterprise assets that are connected to both the Internet and each other. In IoE, these things will sense more data, become context-aware, and provide more experiential information to help people and machines make more relevant and valuable decisions. Examples of "things" in IoE include smart sensors built into structures like bridges, and disposable sensors that will be placed on everyday items such as milk cartons |
| **Process** | Process plays an important role in how each of these entities — people, data, and things — works with the others to deliver value in the connected world of IoE. With the correct process, connections become relevant and add value because the right information is delivered to the right person at the right time in the most appropriate way |

Source: Mitchell et al., 2013, p. 2

### 1.2 Economic and social impact of IoT

A study conducted by McKinsey Global Institute reports that IOT has the potential to generate a financial impact of $2.7 trillion to $6.2 trillion per year by 2025. This study analyzes several industries and reaches to the conclusion that the largest impact results from the healthcare and industry sectors. The following table illustrates this impact.

Table 2. Impact of IoT on health care and industry by 2025

| Industry | Potential economic impact in 2025 ($trillion, annually) | Estimated scope/size of problem in 2025 | Estimated potential reach/penetration in 2025 | Potential productivity or value gains in 2025 |
|---|---|---|---|---|
| Healthcare | $1.1 - $2.5 trillion | $15.5 trillion cost of treating chronic diseases | 70-80% mobile penetration in patients who account for bulk of health-care spending | 10-20% reduction in chronic disease treatment costs through remote health monitoring |
| | | $400 billion cost of counterfeit drugs, 40% addressable with sensors | Counterfeit drug tracking. Developed world:50-80%. Developing world: 20-50% | 80-100% reduction in drug counterfeiting |
| | | 50 million nurses for inpatient monitoring | Inpatient monitoring. Developed world:75-100%. Developing world: 0-50% | 0.5-1.0 hour time saved per day by nurses |
| Manufacturing | $0.9 - $2.3 trillion | $47 trillion in global manufacturing operating costs | 80-100% of all manufacturing | 2.5-5.0% saving in operating costs, including maintenance and input efficiencies |

Source: Woodside Capital Partners, 2015, p. 7

BCS - The Chartered Institute for IT (2013) refers to the social impact of IoT, which consists of the following elements:

- Organizational and institutional innovation is the key to the sustainability of IoT as it will change the way things are done.
- Problems could arise from creating large amounts of data that are not necessarily precious or necessary and can be used in a way that leads to invalid conclusions. But the data generated during everyday life and work will also have great opportunities, for example in designing more efficient transport systems.

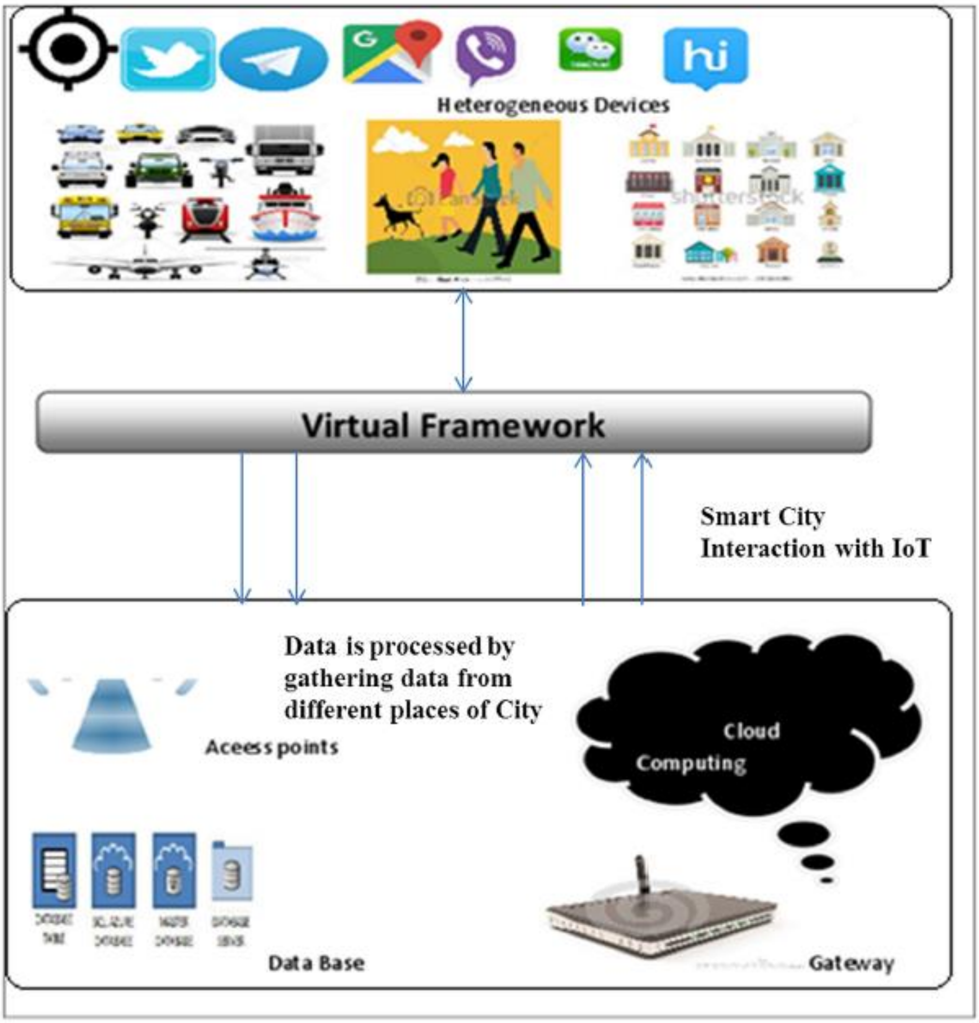
- Public attitudes, attitudes and behaviors will be critical if the citizen is more interested in privacy, data protection and other social issues of IoT - as opposed to the potential benefits of public security, energy saving and lower costs.
- Privacy and data protection will depend on how people feel they are giving, marketing, or allowing others to collect information based on their behavior.
- IoT could lead to increasingly high-tech, high-tech systems that can remove human intervention in order to increase their credibility and increase the chances of social vulnerability as a result of piracy or major conflict conditions.
- The question of whether Internet continuity will inevitably lead to higher quality in the provision of many services is problematic.
- There may be inequalities in accessing value data for individuals and communities from the Internet, along with other digital divide between societies.

### 1.3 Enabling technologies and architectures

In today's world, cities face a series of challenges such as economic growth, social security, control and job creation, environmental monitoring. For these challenges, the Internet has become a crucial factor in a future planning. Due to the benefits of IoT and the challenges faced by cities, digital urban design is becoming quite attractive and quickly attracts the interest of architects, transport organizations and public services. IoT is the basic architecture for the implementation of intelligent urban projects and is flexible enough to meet the dynamic demands of people. Innovative technology, Defined Networking Software (SDN), and Network Virtualization (NFV) can accelerate the optimization of IoT architectures. Encouraged by the benefits of pairing SDN and NFV, Ahmed and Rani (2018) propose a smart IoT simulation software (ISSIoT). Utilizing the benefits of software modules and intelligent communication, they disconnect virtualization from hardware devices. ISS-IoT extends the ISS approach from sensor network platforms to smart applications, enabling intelligent communication for data transmission, processing and reporting (Ahmed & Rani, 2018).

The figure below depicts the use of the proposed architecture, comprised of cloud computing servers, control gates, processing, transmission and retrieval of intelligent cities through virtualization. Upstairs, many smart city applications are installed and each application requirement is different and customized. Using APIs can simplify application service, and using the same physical architecture can reduce overall costs (deployment, maintenance, operation, and processing costs.) Smart communication can provide the best end user solution and the control gates are accessible through authorization, which further increases security. These features make ISSIoT a potential architecture and an innovative vision for to serve the requirements of different applications and thereby to facilitate the sense of the smart city (Ahmed & Rani, 2018).

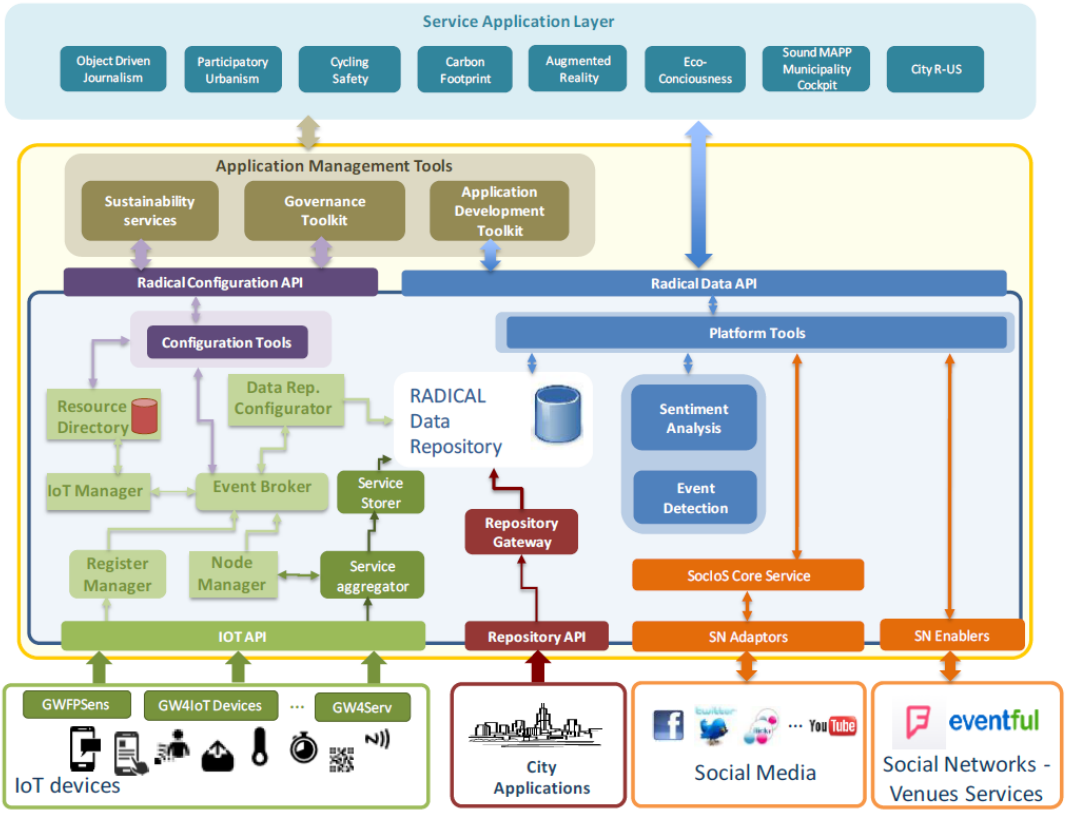
Figure 2. Interaction of heterogeneous devices within ISS-IoT




Source: Ahmed and Rani, 2018

One more technology / architecture proposed is the RADICAL approach, which is a SOA (Service Oriented Architecture)-based platform that allows the collection of big data stemming from social networking (SN) sites and Internet of Things (IoT) devices smart city applications. The architecture of this platform is illustrated in the figure below. This approach place emphasis on the one hand on environmental sustainability and on the other on business viability. Thus, sustainability and governance are the two major concerns of this platform, which allows the addition of services based on users' proposals and the involvement of cities' Living Labs. The goal of this approach is to produce a testbed for applying multiple analysis functionalities and techniques.

Figure 3. Architecture of the RADICAL approach




Source: Psomakelis et al., 2016

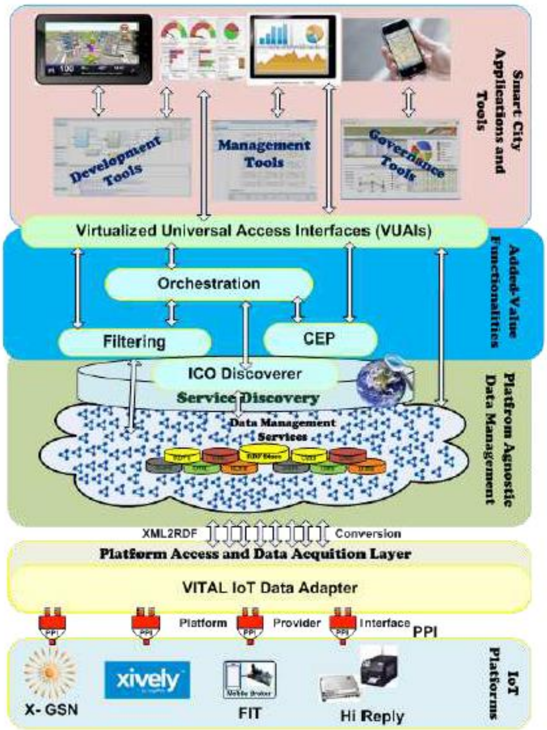
Box 2. Living Labs and Open Innovaion

In a world of ever more complex problems and widely distributed knowledge, it is hard for a company to rely entirely on its own research and skills, not least if it is to develop the smart solutions needed for future cities. Therefore, many companies open themselves up to include external partners in the innovation and development process of new products or services. This process is called open innovation. There are many ways of achieving open innovation. One approach, which is widely used in connection with Smart City developments, is the living lab approach. In a living lab, researchers, firms, users, public partners and other stakeholders in emerging technologies collaborate on innovation processes in a real-world setting, such as a city. It is important not just to focus on the technological aspects of Smart City solutions as these have to be able to function in the real-life, social setting of the city: If you only focus on technology and not on human behaviour, you will not become smart. In this regard, living labs are unique tools in the innovation process leading to smart solutions as they have a user-centric approach to innovation, which involves the citizens of the city in their everyday use. This allows for user influence on the innovation process. Many of the current cities working to become smart are designed as living labs, where data from the citizens' use of the city create a solid base for informed political decisions and technological developments.

Source: Copenhagen Cleantech Cluster, 2012, p. 13

One more technology that can be used along with IoT in a smart city environment is Cloud of Things. Petrolo et al. (2014) introduced the VITAL approach, which is a CoT-based platform. Therefore it can provide Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Thus, this platform can meet the requirements of a smart city, namely citizen-centric service/application and operational on behalf of the authorities. VITAL's aim is to integrate sensors and interconnected objects among multiple IoT platforms and ecosystems. According to the researchers, the key "is the virtualization of interfaces that in combination with cross-context tools enable the access and management of heterogeneous objects supported by different platforms and managed by different administrative stakeholders" (Petrolo et al., 2014, p. 5). The overview of this architecture is depicted in the following figure.

Figure 4. The VITAL platform




Source: Petrolo et al., 2014, p. 15

So far, projects and initiatives under the generic term "Internet of Things" (IoT) have mainly focused on creating connectivity in a variety of difficult and limited networking environments. A promising next step is to create expandable interaction models above this basic network connectivity and therefore the focus on application level. In the Web of Things concept, smart things and their services are fully integrated into the Web by reusing and customizing the technologies and templates commonly used for traditional web content. In particular, small Web servers are embedded in smart things and the REST architectural style is applied to resources in the physical world. The essence of REST is to focus on creating loosely linked Web services so they can be easily reused. REST is the architectural style of the web (implemented by URIs, HTTP and standard media types, such as HTML and Extensible Markup Language (XML)) and uses URIs to track web resources. It provides services in a uniform interface (HTTP methods) from the semantics of their application and provides mechanisms for users to choose the best possible representations for interactions, making it an ideal candidate for building a "universal" architecture and Interface Programming Interface (API) for smart things like the smart city (Guinard et al., 2010).

The central concept of REST revolves around the concept of a resource as every component of an application that deserves to be uniquely identified and linked. On the Internet, resource recognition is based on Uniform Resource Identifiers (URI), and performances retrieved through resource interactions contain links to other resources so that applications can follow links through an interconnected resource web. Users of REST Services are supposed to follow these links, just like someone is browsing websites in order to find resources to interact. This allows users to "explore" a service simply by browsing it, and in many cases the services will use a variety of link types to determine different relationships between resources. Resources are abstract entities and are not bound by any specific representation. Thus, various forms can be used to represent a unique resource. However, agreed forms of resource representation make it much easier for a decentralized system of users and servers to interact without the need for individual negotiations. In the web, HTTP media support and Hypertext Markup Language (HTML) allow independent collaboration and user browsing using hyperlinks (Guinard et al., 2010).

Key points of the REST architecture proposed by Guinard et al. (2010) are the following:

- In the case of smart things, support is recommended for at least one HTML representation to ensure human readability. Because HTML is a pretty detailed form, it may not be served directly by the things themselves, but by intermediaries. For machine to machine communications (M2M), JSON is recommended. Since JSON is more lightweight than XML, it is believed by writers to be better suited to devices with limited capabilities such as smart things. Additionally, it can be directly analyzed in JavaScript objects. This makes it an ideal candidate for integration into Web Mashups
- In the REST architecture, interaction with resources and the retrieval of their performances takes place through a single interface that defines a service contract between the user-computers and the servers. The unified

interface is based on resource recognition (and therefore interaction), and in the case of the web, this interface is defined by HTTP. Three specific parts of this interface are:

- Functions: HTTP provides four main methods of interaction with resources, often referred to as "verbs": GET, PUT, POST and DELETE. GET is used to retrieve the representation of a resource. PUT is used to update the status of an existing resource or to create a resource by providing its ID. POST creates a new resource without specifying an identifier. DELETE is used to remove (or "unlink") a resource. In the Web of Things, these acts are probably mapped naturally, since intelligent things usually offer simple and individual functions
- Negotiation of content: HTTP also establishes a mechanism for customers and servers to communicate about the requested and provided representations for any given source. This mechanism is called content negotiation. Since content negotiation is integrated into the uniform HTTP interface, users and servers have agreed on ways in which they can exchange information about requested and available resource representations, and negotiation allows users and servers to choose the best representation for a specific scenario.

➢ Status codes: The status of a response is represented by standard status codes sent back as part of the header in the HTTP message. In a Web of Things, this is extremely useful as it gives a 'lightweight' but also powerful way of updating for abnormal execution requests.

What should be mentioned, however, is that the technical infrastructure used in a smart city will be determined on the basis of how well it (Mitchell et al., 2013):

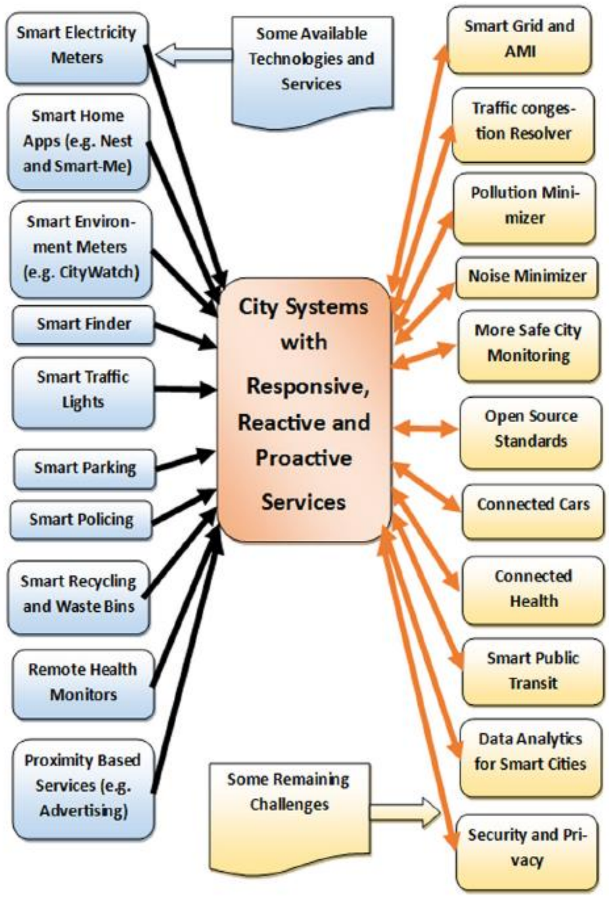
1. Interconnects people, machines, and sensors throughout the city
2. Securely collects real-time and context-aware data from multiple sources
3. Stores data from devices, people, and applications

4. Organizes data by using semantic links to identify and send it to relevant users
5. Analyzes data by interpreting and correlating patterns of use
6. Shares information with end users and publishes linked data based on semantics
7. Enables an open ecosystem for innovation to develop new services that appeal to both citizens and city leaders

### 1.4 Obstacles and challenges in the implementation of smart city services

Overall, the figure below illustrates the available IoT technologies for smart cities, as well as the challenges that arise.

Figure 5. Smart cities and IoT: Available technologies and challenges




Source: Kim et al.., 2017, p. 160

In smart cities, several IoT devices and related services are available to locate, intelligently identify, monitor, and manage data from citizens. One of the challenges of these environments is to allow mobile users to seamlessly consume the services they offer, and often combine functions offered by software and hardware resources anywhere and at any time (Urbieta et al., 2017).

An interesting study was conducted by Anthopoulos (2017), who examined the case of ten smart cities, in order to reach a conclusion regarding the existence of the smart city against smart utopia, i.e. whether smart cities are really smart cities. The smart city, which began in 1994, evolved mainly after 2011, and it goes along with the concept of the city. In this framework, smart city is in principle a city, whose performance is essentially based on urban infrastructure, facilities and urban planning. Hence, if the city has sufficient services of general interest and strong economic capacity (such as the cities of London, New York and Hong Kong, etc.), it performs well and offers opportunities to its citizens, regardless of its intelligent facilities. In addition, if the city follows sustainable planning, it has plenty of open spaces and ensures the satisfaction of citizens, it is more likely to become a city that people can live in (i.ee Melbourne, Vienna and New Songdo). On the other hand, intelligence has been recognized as an innovation based on ICT. In this context, a city could be considered intelligent, even if it does not have ICT-based infrastructure or services but serves local information needs (such as Geneva). However, the paradox is that all smart city models consider this intelligence to be ICT-based, although they provide urban performance indicators that measure all types of local capacity. Consequently, the corresponding measurements should be identified focusing only on ICT-based smart capacities

According to the researchers, none of the cases of the cities they have examined concerns a urban utopia and in this respect the citizens will have to reconsider their expectations from a smart city and realize that it is aimed at improving local life against certain challenges climate change, economic growth, etc., as well as the strengthening of urban planning. Even a visit to New Songdo's "City of Tomorrow" does not give the person a sense of life in the future and is more likely for residents to experience up-to-date or fully automated standard services (i.e. garbage collection, remote control and heating systems). Since some utopic expectations can easily be created after a debate on the smart city, some cities seem to attract people interested in technology and planning (ie Melbourne, Tampere, London, and Vienna).

Particularly important is the issue of privacy and trust. Privacy issues arise from the elaboration of detailed data on consumer behavior and the generation of predictive models for energy, water and transport use. It is not difficult to imagine a future information system across the city, due to the sensors at home, the means of transport and the digital traces collected by the digital transfer ticket. Removing such a system may not be easy if it entailed the unavailability of basic services such as heating or transport or the requirement to pay premiums. To achieve this, public IoT infrastructures require broad public support, which can only be achieved through a wide commitment of citizens and measures to help citizens understand the purpose and the consequences of the proposed developments. If this is not done early, one can expect resistance from those who will eventually be affected by these developments. Many smart energy projects in the US and Europe have already been abandoned because consumers have not trusted the intentions of energy companies to install smart cash at home (BCS - The Chartered Institute for IT, 2013).

Another area of interest to these systems across the city, that is to say the intelligent city architecture, is related to the development processes and methods used to build them. Many of them start with preliminary specifications and are based on a detailed delivery plan, as the system can be predicted and fully defined before it is built and the key challenge is to minimize the risks and costs of the project. In this sense, many of these projects follow a classical model of public sector development. This model may be inappropriate, since it is unlikely that an IoT polarization system can be fully defined throughout the city. Many of the underlying concepts are still unknown (e.g. what are the appropriate privacy models that support the exchange of personal identifiable information in an ecosystem of private and commercial entities that simultaneously satisfy end-user preferences), while at the same time the properties of complex IoT systems are emerging properties (e.g. peer supervision with smart meters), which can only be fully understood after their development (BCS - The Chartered Institute for IT, 2013).

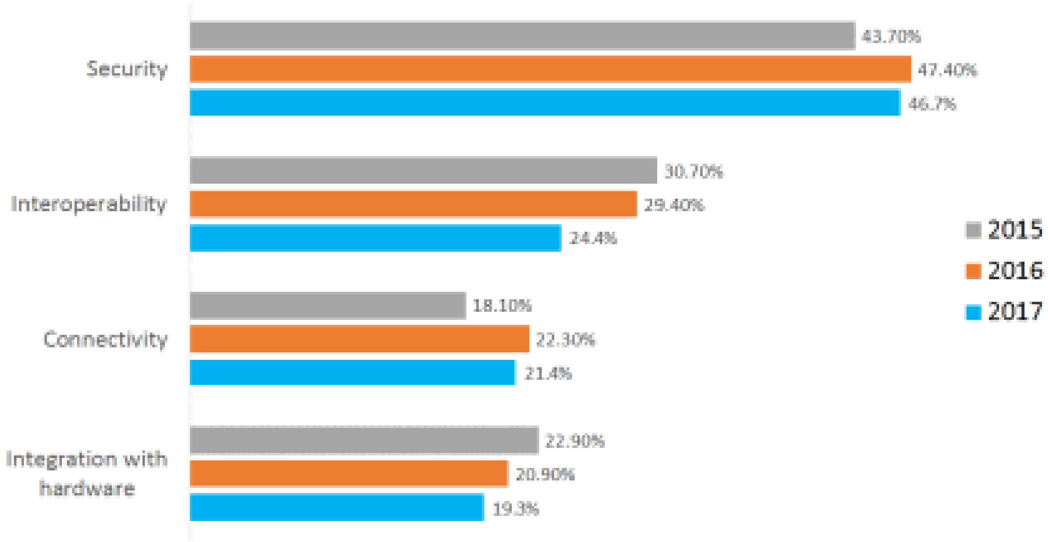
According to Saidu et al. (2015), for multiple devices to communicate with each other, there are challenges in managing the communication of these devices. This in turn means that the devices should provide some smart functionality. This intelligent functionality is grouped into the following five categories (Saidu et al., 2015):

1. Saving information: Traditionally, information is stored in databases or on database servers, depending on the size of the organization or for what information is required. The information stored by these smart devices can either be static (eg production / expiry date, inventory records and owners) or dynamic (eg temperature, location, device in use or static). This information can be stored in a number of ways ranging from read-write or read-only and can also be stored in disks, bar codes, etc. A team of researchers from Microsoft and Texas University at Austin have developed an archiving system called "Bolt". This system combines and filters information from various detectors, allowing various electronic devices such as refrigerators, surveillance cameras, or heaters to transfer data to a secure remote storage location, such as a cloud computing system, for sharing with other devices in other locations.
2. Gathering information: Devices may also be required to collect information autonomously for a variety of reasons. Such information could include room temperatures for heating appliances, locations or even time or duration. In addition to object tracking, information on maintenance checks can be collected. Knightscope, a company founded by William Santana Li, created a series of "automatic data engines" (i.e. k5 and k10). These machines are expected to gather environmental information and feedback to organizations that aim to help build their data and improve critical decision-making. The creators expect these devices to be used in areas that will be used to track construction progress, help keep inventory in industries, and even for various research purposes, such as collecting statistics.

3. Communication / Protocols: The ability to exchange data between each other and servers over the internet or other communication platforms is feasible in a wired or wireless scenario. Wireless communication is possible via radio, light waves or sound waves. Device communication is important for alerts to other devices or users of these devices.
4. Processing of information: IoT utilizes the data collected by various decision making devices and predefined actions. The processor of a digital computer processes information to produce comprehensible results. Processing involves collecting information, recording, assembling bits, retrieving or disseminating information. IoT means that many elements in a given environment require internet access and data processing. Large amounts of data will need to be processed each time, making it necessary for sophisticated microcontrollers and microprocessors to be able to communicate with other devices in their environment.
5. Performing actions: Items that are equipped with IoT microcontrollers may also be able to take action based on the data provided. Such actions could be, for example, triggering a heater or even door locking or alarms setting and includes any action that could affect the current state of the real world

According to the IoT Developer Survey 2017, the issues that should be considered concerning IoT are the following: security, interoperability, connectivity. This concerns are illustrated in the following figure.

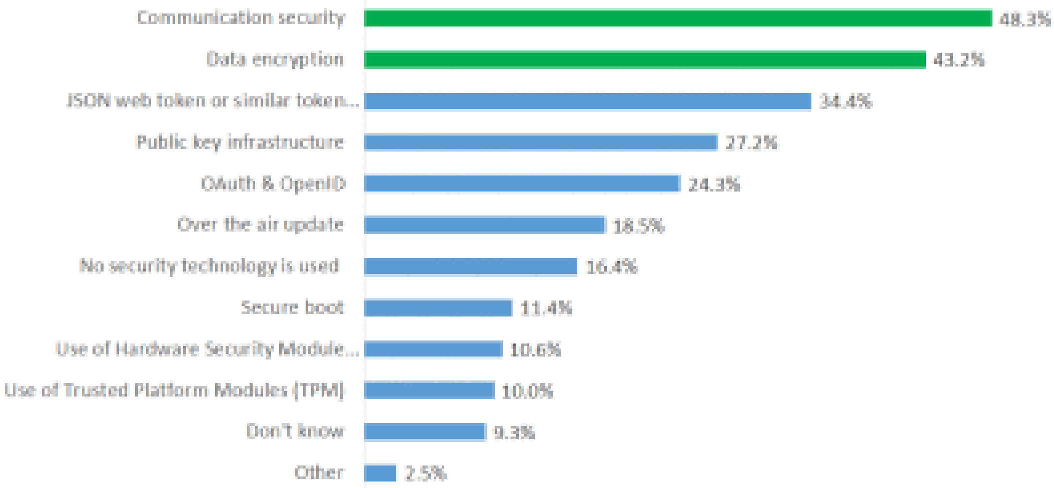
Figure 6. Concerns about IoT




Source: IoT Developer Trends 2017 Edition, 2017

Regarding the security-related technologies in the case of IoT, the following figure depicts the existing software technologies: Communication Security (TLS, DTLS) and Data Encryption. Security technologies that are not so popular include Trusted Platform Modules, Hardware Security Modules and Over the Air Update.

Figure 7. Security technologies in IoT




Source: IoT Developer Trends 2017 Edition, 2017

In the context of using both IoT and WoT, specific challenges also emerge. These challenges, according to Kamilaris and Pitsillides (2016), are the following:

a. Heterogeneity due to IoT / WoT devices / services that provide proprietary communication protocols or heterogeneous consumer data with different requirements and needs. In the first case, although implementation-level communication becomes standardized through the WoT principles, lower-level interaction remains a challenge. In the last scenario, some users may request information in real time, while others may need historical data. Their needs in terms of data quality, spatial resolution and sampling rates vary, so IoT / WoT and mobile computing need to support a variety of applications and requirements.
b. Continuous detection. Some mobile applications supported by IoT / WoT require continuous detection, signal processing, analysis and extraction of conclusions that require more clarity of computing, memory, storage, and communication. Suggested approaches include sending only specific summaries (rather than raw data) or incorporating tolerable delay models tailored to the needs of the application. Occasional detection could be another option in which detection is a secondary, low priority feature on the mobile device.
c. The sense of crowd. The participative sense and the sense of crowd of mobiles have several open issues, which include questions about how to measure detection opportunities and the quality of detection, how to handle incomplete, noisy and unreliable data , how many mobile users can provide enough detection opportunities to achieve the required detection quality, how to deal with the fact that people are always moving around a range of popular sites instead of purely random moves, how to deal with the fact that each person shows a preference for certain specific locations, and how to avoid using a large proportion of the battery that could prevent users from accessing their usual services.
d. There is a content problem that happens because phones may be exposed to events for a very short time (e.g. if the user is traveling fast, if the event is local and spontaneous, as in the case of sound, or if the sensor takes longer to collect a sample, as in the case of an air quality

sensor). Telephone calls could also interfere with collecting relevant data.

e. Security is a top priority in mobile telephony and becomes more important when interacting with IoT / WoT. A practical issue is to ensure the security of shared resources (eg WoT devices / services) against misuse by unauthorized mobile users. Relaying infrastructures for secure access to embedded systems such as Yaler could be a response to this challenge.

f. Privacy in the exchange of personal information over the Internet is one of the most important challenges. Some privacy approaches include AnonySense, which suggests an anonymity concept through k-anonymous tasking and the SAC, an attorney for authentication between users (mobile) and smart things.

g. Reliability is particularly important in specific applications, such as in user health monitoring applications. In these cases, the measurements must be reliable and accurate and the corresponding mobile applications should be able to detect abnormalities and errors in the data, which could generate false signals (eg symptoms). Reliability also relates to how well mobile phones can interpret human behavior from low-level multimodal sensor data or similarly how they can infer the environment (eg, pollution). UrbanRadar has suggested urban mashups as a way to infer various environmental conditions from more basic WoT-based services.

h. Search and discovery are vital to locating local and / or related real-world devices (and / or people) who take advantage of their services to create more advanced knowledge. WoT has not yet standardized some technique for real-time discovery of individuals and their services, but some efforts have been put forward in this direction

i. Personalization is expected to pay particular attention to interacting with IoT / WoT through mobile computing. For example, sports applications could capture the personal characteristics and achievements of users to suggest realistic short and long-term goals.

My2cents can record consumer buying habits and suggest relevant short-term deals to consumers. Mobile computing, being personalized in a user's profile, empowers him to make more informed decisions on a range of WoT-enabled services.

j. Emotional analysis is related to personalization, as it allows the provision of better services to users depending on their responses to the features provided by mobile applications. Research in this area involves feeling unconscious, with the aim of quantifying and recording aspects of the behavior of people who are not known. Mood recognition also applies to working environments to benefit workers' health and productivity

k. Mobile computing is an open field of research that creates design elements and exploits various psychological / sociological factors that influence users to change their behavior towards a better quality of life, a more sustainable life, environmental consciousness. The connection between laptops and IoT / WoT offers great new opportunities to examine what design features of mobile applications and which drivers can influence users to challenge and change their behavior and lifestyle. A big challenge related to persuasion is how to deal with the fact that people tend to lose interest after receiving feedback for a few weeks or months.

l. Large data analysis is a necessary step in most participatory detection applications in order to extract useful information from huge amounts of real-world data flows. In this respect, an open, standardized methodology for IoT / WoT analytical problems is still non-existent. Significant for researchers in this field is the availability of relevant data sets. CrowdSignals.io aims to create the widest range of rich, timeless mobile and sensor data recorded by smartphones and smart clocks such as user interactions, social connections and communications as well as research feedback.

m. Merging the digital and natural world through web and mobile technologies is profitable for businesses worldwide, but specific research is needed in this field. Everything is a newly established company that seeks to demonstrate, via various case studies, the economic viability of IoT / WoT-based investments. The solutions offered include brand protection, inventory management, consumer confidence and involvement, data tracking and analysis.

Apart from the above, Hernández-Muñoz et al. (2011) refer to yet another challenge: the Future Internet. The authors argue that, once significant challenges of integrated ICT platforms are identified at urban level, it is clear that the future development of smart cities will only be achieved in conjunction with a technological leap in the infrastructure of these ICTs. The authors are of the opinion that this technological leap can be done by embracing smart cities as the Future Internet. Although there is no universally accepted definition of the Future Internet, it can be defined as a socio-technical system that includes information and services accessible from the Internet, combined with the natural environment and human behavior and supporting smart applications of social significance. Thus, the Future Internet can turn a smart city into an open innovation platform that supports vertical business applications based on horizontal technologies. IOT is one of the three pillars of the Future Internet to shape an intelligent city environment.

In this context, Hernández-Muñoz et al. (2011) report that there is a two-way relationship between the Future Internet and Smart Cities: on the one hand, the Future Internet can provide solutions to many challenges facing a smart city, while smart cities, on the other hand, provide an excellent experimental environment for the development, experimentation and control of common Future Internet service mechanisms required to achieve "intelligence" in a variety of applications. However, in order to fully develop the example of a smart city, a broader geographical area requires a better understanding of various issues such as capacity, extension, interoperability and stimulating faster development of new and innovative applications. This knowledge must be taken into account to influence the specifications of Future Internet Architecture design. The availability of such infrastructures is expected to stimulate the development of new services and applications by different types of users and help to collect a more realistic assessment of the users' perspective through acceptance tests of these technologies.

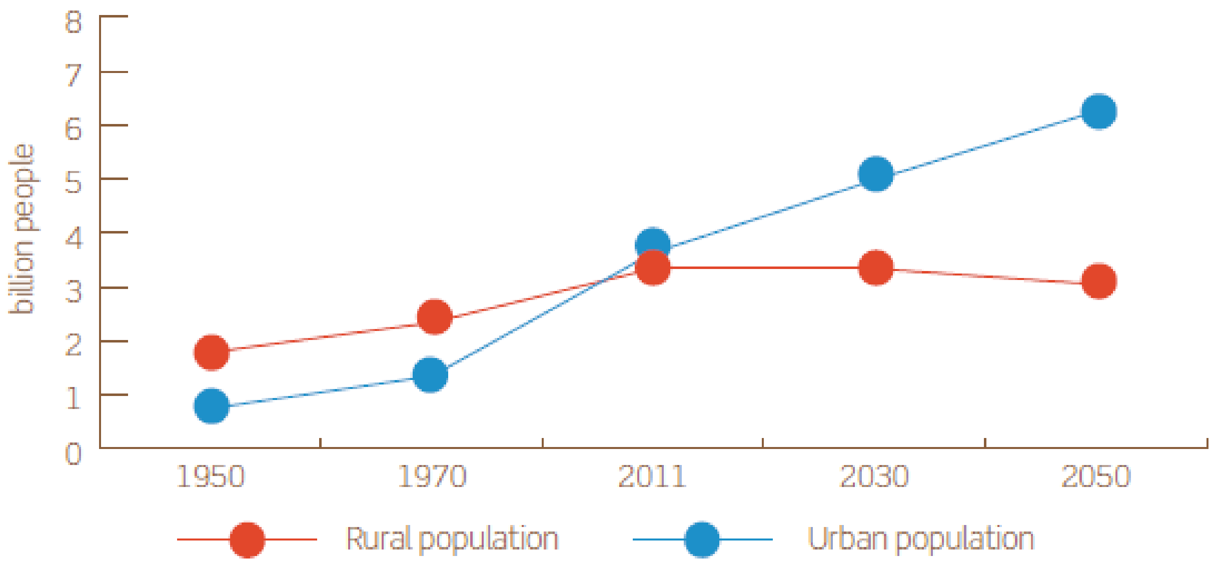
Finally, according to the National Institute of Standards and Technology (2016), two obstacles currently exist for effective and powerful solutions in smart cities. First, many modern ICT applications for smart cities are based on customized systems that are not interoperable, portable in cities, scalable or cost-effective. Secondly, some architectural design efforts (e.g. ISO / IEC JTC1, IEC, IEEE, ITU and joint ventures) are in progress but have not yet converged, creating uncertainty amongst stakeholders. There is a lack of consensus both for a common language / taxonomy and for intelligent city architectural principles. As a result, these groups are likely to produce standard results, including patterns that are different, perhaps even contradictory, that do not serve the global smart city community.

## CHAPTER 2. SMART CITY APPLICATIONS

### 2.1 Smart city implementation based on IoT

Smart city becomes even more important today, due to the pressures exercised upon cities because of the urbanization process. These pressures are both positive (e.g. the formation of knowledge-driven economies, ability to integrate many systems and networks into one another) and negative (e.g. climate change and environmental pollution in cities). It is estimated that every week about one million people move from rural areas into urban areas, driven by the economic opportunities that the cities offer. More precisely, close to 4 billion of the world's current population of 7 billion now live in urban areas. This number is expected to increase to 6 billion people by 2050, most of whom will live in developing and less-developed countries. The tendency towards urbanization is depicted in the following figure.

Figure 8. World urbanization prospects




Source: Copenhagen Cleantech Cluster, 2012, p. 4

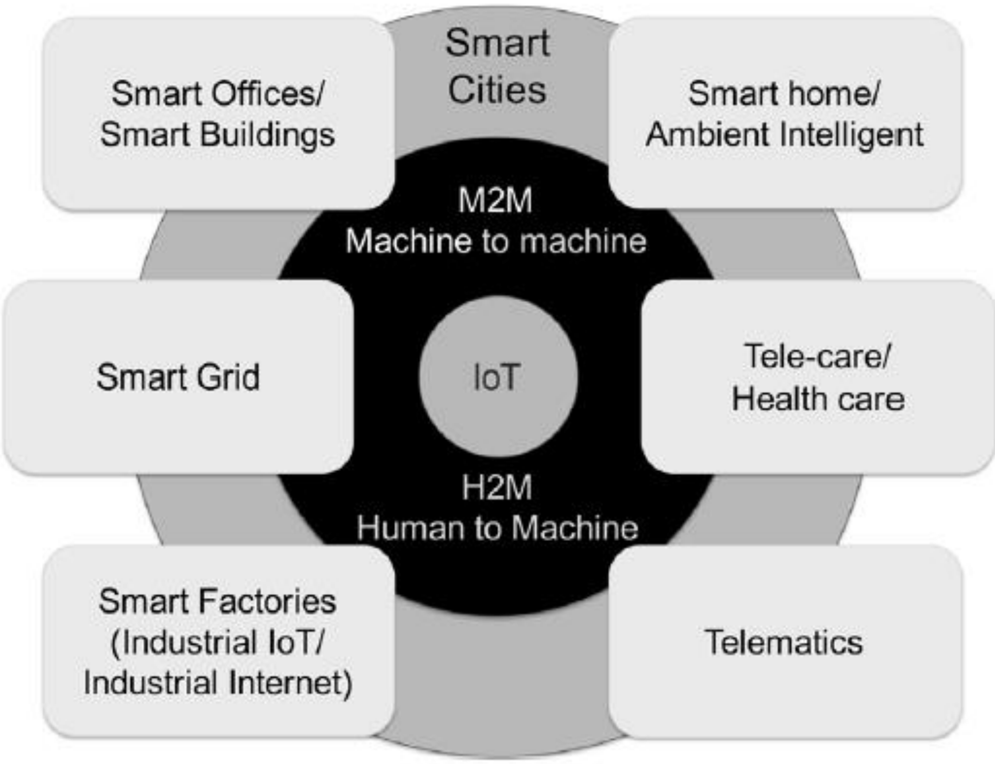
Box 3. Smart city Development

The global trends within urban development have been monitored in a recent report by the McKinsey Global Institute (MGI). This concludes that the centre of gravity of the earth's urban landscape is changing rapidly. Within the next 15 years, 136 of the cities from the developed world listed in the top 600 cities index (The index is based on the MGI Cityscope, a global database containing information about more than 2,000 cities) will be replaced by cities from developing countries. Not surprisingly, more than 100 of these will be Chinese2. While this implies the dawn of a new era where non-OECD cities will play a decisive role in the world's economy, it also points to the fact that a very substantial part of Smart City developments are taking place outside of Europe and North America.

Source: Source: Copenhagen Cleantech Cluster, 2012, p. 9

Smart cities apply IT technologies on a very wide scale by linking people to a city with all the "smart technologies" of IT, in order to provide real-time information to selected users with correct details at the right time (Hui et al., 2017; Farahani et al., 2018). The figure below illustrates a typical integration of smart technologies into a city architecture.

Figure 9. Typical architecture of a smart city through IoT

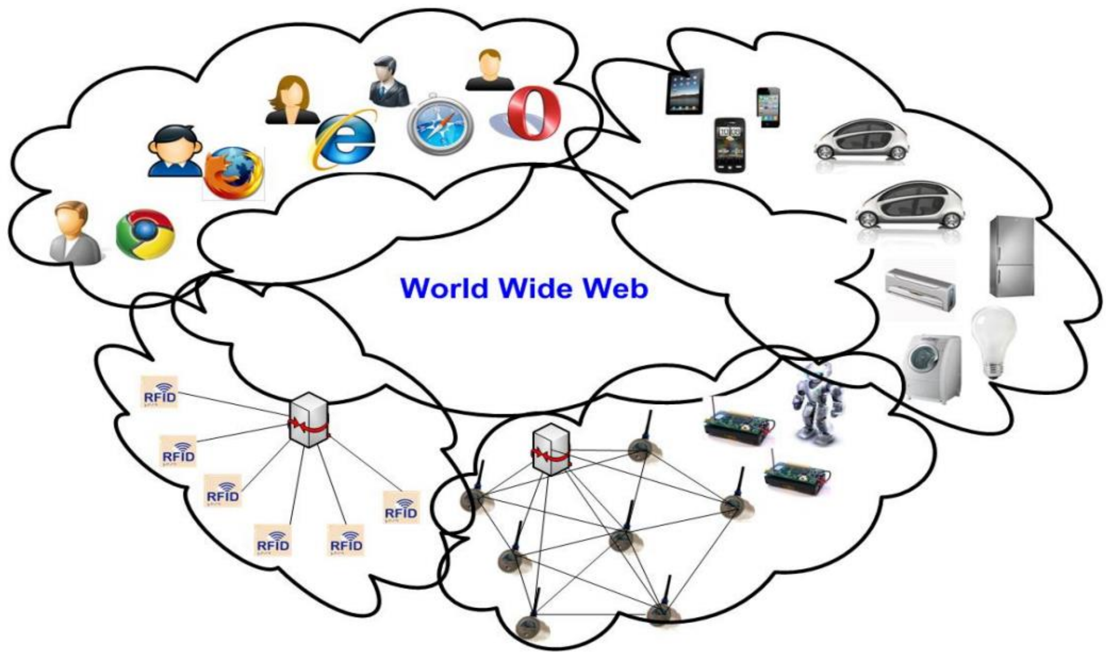



Source: Hui et al., 2017, p. 359

IoT becomes a reality, as everyday physical objects are equipped with sensors, while they are also interconnected, allowing the interaction among them via the Internet. The transfer of IPs to embedded devices has been a successful attempt and, along with the introduction of IPv6 (which offers extremely large addressing capabilities), the merge of the physical and digital world has been facilitated. Based on the concept of IoT, the Web of Things (WoT) repeats well-defined web techniques for linking this new generation of Internet-capable physical devices (Kamilaris & Pitsillides, 2016). While IoT focuses on the interconnection of heterogeneous devices at the network level, WoT can be considered as a promising practice to achieve interoperability at the application level. Through WoT the web can be 'downloaded' and be expanded; the result is that every user can connect devices to this network (Kamilaris & Pitsillides, 2016). Intelligent object web activation offers great flexibility and customization capabilities for end-users. For example, end-users who are familiar with new technologies can easily create small applications on their devices. Following the tendency of Web 2.0 participatory services, users can create applications that combine real-world devices, such as home appliances, with virtual Web services. This type of application is often referred to as natural Mashup. In the web, this type of small, ad-hoc application is usually created through a Mashup processor (e.g. Yahoo Pipes3), a web platform that allows technology users, namely experienced technology users, to create visually simple rules for the writing of websites and data sources (Guinard et al., 2010).

The vision of WoT allows the discovery, synthesis and execution of various web services. This enhances the breadth of traditional Internet services by promoting the web from cyberweights and web services. In addition, WoT is in fact a service ecosystem that is used on the one hand to add more services, and on the other to orchestrate different kinds of services in a noble way, making services more human-oriented and intelligent. The following figure illustrates the concept of WoT.

Figure 10. Web of Things




Source: Zeng et al., 2011, p. 427

As both IoT and WoT are growing in a rapid way, their interconnection with mobile devices is also rising. Built-in mobile phone sensors combined with real-world devices have the ability to improve the overall knowledge, perception and experience of users, encouraging most informed choices and better decision-making process. Within this framework, there are ten categories of interactions between IOT, WoT and mobile computing according to Kamilaris and Pitsillides (2016), which are depicted in the following table.

Table 3. Interaction categories among IoT, WoT and mobile computing within the framework of smart cities

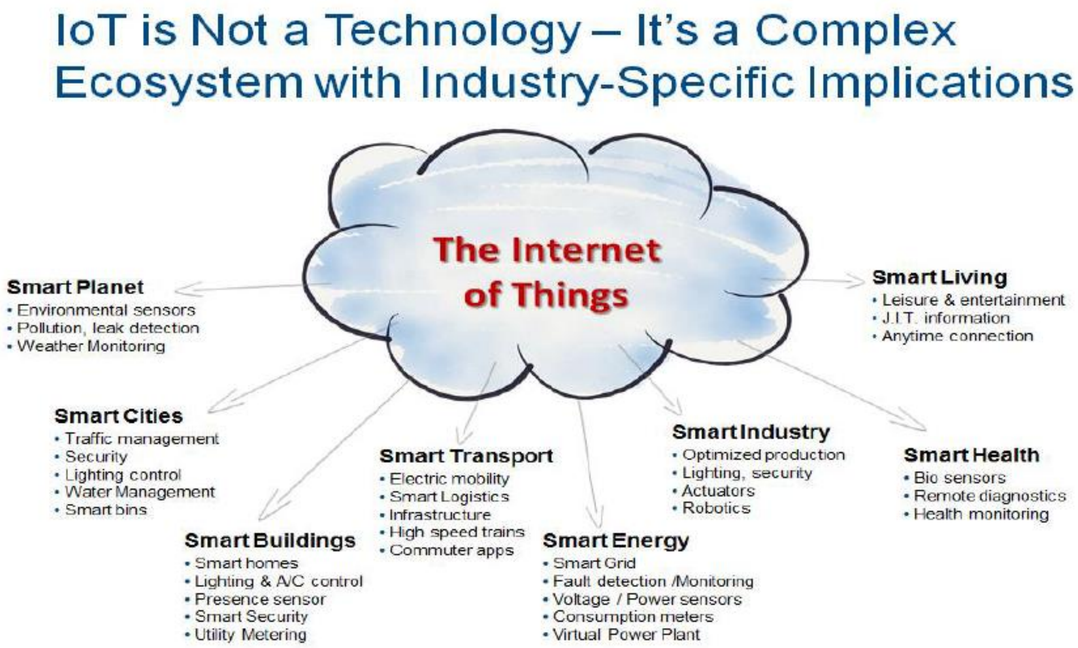
| **Interaction category** | **Details and examples** |
| --- | --- |
| **Participatory sense** | It involves mobile systems that encourage users to record and share information in the direction of co-creation of advanced knowledge. Popular technologies used in this category are: GPS, camera, microphone. |

| | |
|---|---|
| **Ecological observations** | Refers to mobile applications that provide feedback to users about different environmental phenomena or events, or information about their personal consumption (water, electricity, energy, etc.). Popular technologies used in this category are: camera, power screens, smart meters, barcodes, and environmental sensors such as air quality. |
| **Activation and control** | Refers to mobile applications that control certain physical devices or trigger events associated with these devices. A typical example is home automation applications within the smart home. Popular technologies used in this category are: Smart Meters, Smart Devices, Light Switches, Smart Factory Sensors / Activators |
| **Health** | The mobile phone acts as an interface between the body and tissue sensors. It receives information about the user's health status, measured by various sensor devices installed in the user's body, and then uploads / shares this information to the web for better analysis, comparisons and feedback. Popular technologies used in this category are: Body space sensors, GPS, microphone, accelerometer, communication applications (e.g. telephone calls, SMS). |
| **Sport** | It includes a combination of natural sensors and mobile applications used during sports activities to capture various measurements and improve performance of the athlete's user. Popular technologies used in this category are: Body space sensors, motion sensors, GPS, pressure sensors (footwear), pacemakers |

| | |
|---|---|
| **Agriculture** | It refers to smart farming practices for improving productivity, animal management and increasing consumer satisfaction and transparency. Popular technologies used in this category are: Portable collars, GPS, barcodes, RFID tags, plant sensors |
| **Gaming** | This category concerns virtual games that look at the physical presence or status of the mobile user to improve the game experience. Popular technologies used in this category are: Accelerometer, gyroscope, camera, pedometer, barcodes, RFID tags |
| **Transportation** | An increasing field in which the sensory features of the mobile phone are utilized for better driving experience and ease of parking. Popular technologies used in this category are: GPS, compass, carrier connectivity, RFID tags |
| **Interaction with the things** | This is the broadest category, as it relates to efforts that focus on the interaction with Internet-enabled physical entities that are available in the near environment, such as tagging technologies. Popular technologies used in this category are: NFC Technologies, RFID Labels, Barcodes, QR Codes, Credit Card Devices |
| **Human social interactions** | In the case the WoT expands so as to include people, it is possible to locate various mobile apps that combine information from online social networking sites with information from mobile phones from nearby users to provide an enhanced social experience. Popular technologies used in this category are: Bluetooth, GPS, camera, microphone |

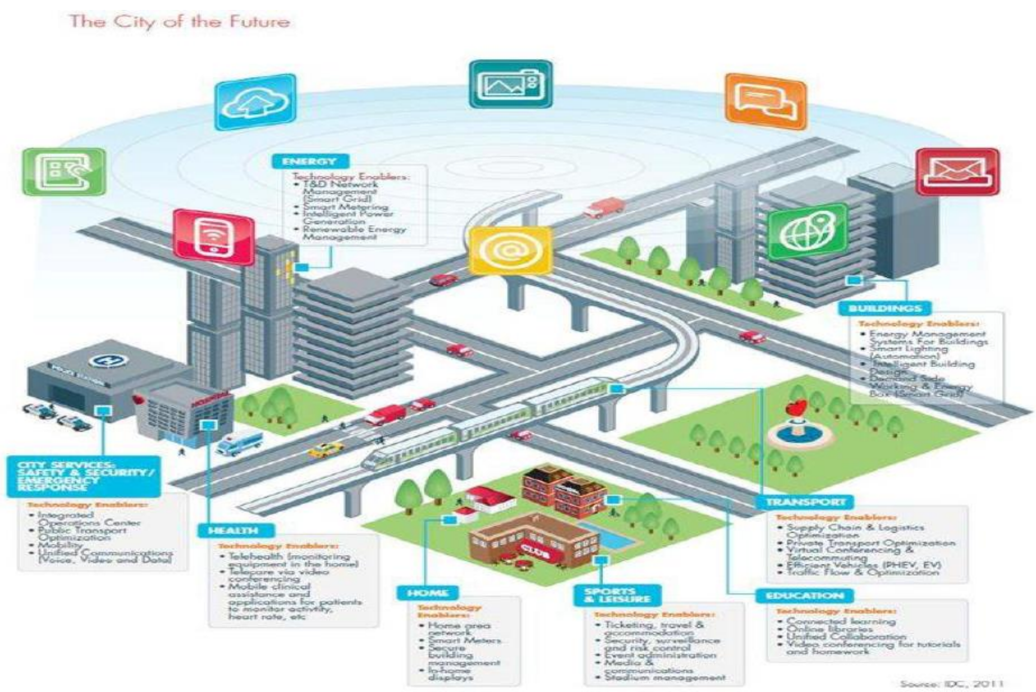
Based on the above, Adisesha et al. (2017) present in their study a detailed depiction of the usage of IoT in a smart city, as illustrated in the two figures below.

Figure 11. Usage of IoT Technology




Source: Adisesha et al., 2017, p. 142

Figure 12. Smart City blue print




Source: Adisesha et al., 2017, p. 142

### 2.2 Current examples of smart cities in mobility, transportation and energy themes

#### 2.2.1 Smart mobility

Smart mobility is a prominent example of IoT and the smart city. Behrendt (2016) suggests that there is a close relationship between smart cities, IoT and intelligent transport. All these three concepts are based on the growing use and experience of networking and of sensor technologies. This means that the smart city tends to focus on the overall urban environment and infrastructure, and IoT is more concerned with the physical elements that make up these network environments. Smart Transport is a baseline scenario for both of them. Technology, citizens and policies are equally important within this scenario, but technology is often presented as a dominant force. A typical example is the self-driving cars.

Today there are two types of vehicle technology, as depicted in the table below: self-driving cars and connected vehicles. Each of these technologies has specific characteristics. The depiction of these characteristics and the brief description of connected vehicles will help in a clearer understanding of self-driving cars and the technology behind these cars.

Table 4. Self-driving vs. connected vehicles

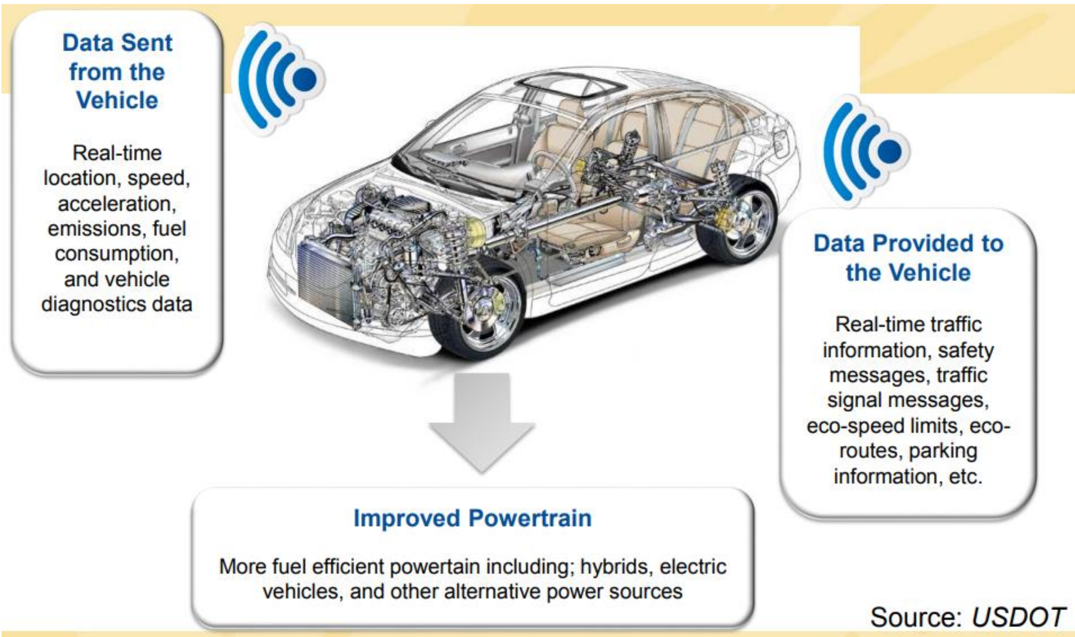
| Self-Driving Vehicle | Connected Vehicle |
|---|---|
| Artificial intelligence is located within the vehicle | Artificial intelligence is wirelessly connected to an external communications network |
| “Outward-facing” in that sensors blast outward from the vehicle to collect information without receiving data inward from other sources | “Inward-facing” with the vehicle receiving external environment information through wireless connectivity, and operational commands from an external entity |

| | |
|---|---|
| Artificial intelligence is used to make autonomous decisions on what is best for the individual driver | Used in cooperation with other pieces of information to make decisions on what is "best" from a system optimal standpoint |
| Artificial intelligence is not shared with other entities beyond the vehicle | Artificial intelligence is shared across multiple vehicles |
| A more "Capitalistic" set-up | A more "Socialistic" set-up |

Source: Pendyala and Bhat, 2014

In fact, connected vehicles make use of technologies and applications that allow them to communicate wireless with a network, so that the vehicles can be connected with other vehicles, roadway infrastructures and consumer devices (e.g. tablets). Thus, there is data sent by the vehicle and data sent to the vehicle, resulting in improved driving, as depicted in the following figure.

Figure 13. Depiction of a connected vehicle

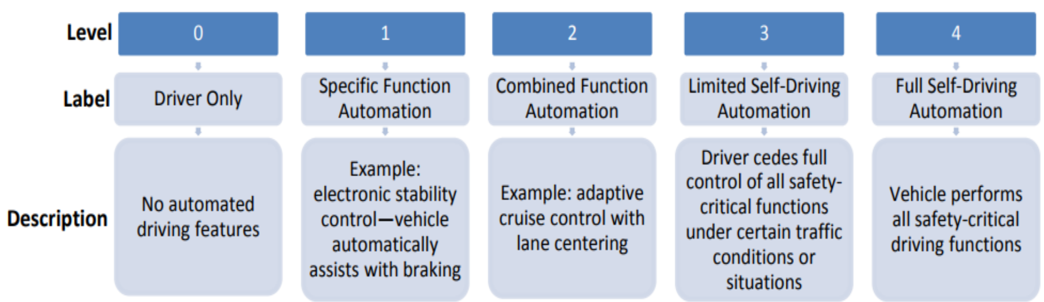



Source: Pendyala and Bhat, 2014

On the contrary, self-driving cars, or else automated vehicles "are defined as vehicles in which at least some aspects of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. AVs use sensors, cameras, light detection and ranging (LIDAR), global positioning systems, and other onboard technology to operate with reduced, limited, and/or no human interaction. AVs represent a continuum of advanced driver assistance systems (ADASs), whereby more and more of the driving tasks are transferred from a driver to a vehicle for both convenience and safety" (Zmud & Sener, 2017, p. 2501). According to Pendyala and Bhat (2014), automated vehicles are "vehicles that are able to guide themselves from an origin to a destination designated by the individual".

In an effort to better define self-driving cars, The National Highway Traffic Safety Administration (NHTSA) acknowledges four levels of automation, as illustrated in the figure below. Level 0 depicts the level of no automation, whereas Level 4 is related to full self-driving automation, where vehicles can operate without any intervention on behalf of humans and can execute all driving functions exclusively by themselves. With regard to the intermediary levels, at Level 1 the vehicle has specific automated functions, at Level 2 the vehicle has multiple automated and integrated functions, whereas at Level 3 the vehicle has enough safety-related functions, enabling the driver not to monitor the roadway all the time.

Figure 14. Levels of vehicle automation




Source: Zmud and Sener, 2017, p. 2502

SAE International Standard has developed a descriptive and technical analysis of the six-level classification mentioned above, as presented in the following table. This table presents the definition and the characteristics of each level of automation. The basic key definitions are as follows (SAE International Standard, 2014):

1. “Dynamic driving task includes the operational (steering, braking, accelerating, monitoring the vehicle and roadway) and tactical (responding to events, determining when to change lanes, turn, use signals, etc.) aspects of the driving task, but not the strategic (determining destinations and waypoints) aspect of the driving task”
2. “Driving mode is a type of driving scenario with characteristic dynamic driving task requirements (e.g., expressway merging, high speed cruising, low speed traffic jam, closed-campus operations, etc.)”
3. “Request to intervene is notification by the automated driving system to a human driver that s/he should promptly begin or resume performance of the dynamic driving task”

Table 5. Definition and characteristics of automation levels

| Level | Name | Definition | Execution of Steering and Acceleration/ Deceleration | Monitoring of Driving Environment | Fallback Performance of Dynamic Driving Task | System Capability (Driving Modes) |
|---|---|---|---|---|---|---|
| **Human driver monitors the driving environment** | | | | | | |
| **0** | No automation | The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems | Human driver | Human driver | Human driver | N/A |
| **1** | Driver assistance | The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human | Human driver and system | Human driver | Human driver | Some driving modes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | driver perform all remaining aspects of the dynamic driving task | | | | |
| **2** | Partial automation | The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task | System | Human driver | Human driver | Some driving modes |
| **Automated driving system ("system") monitors the driving environment** | | | | | | |
| **4** | Conditional Automation | The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the | System | System | Human driver | Some driving modes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | expectation that the human driver will respond appropriately to a request to intervene | | | | |
| **5** | High Automation | The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene | System | System | System | Some driving modes |
| **6** | Full Automation | The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver | System | System | System | All driving modes |

Source: SAE International Standard, 2016

The first benefit of self-driving cars is its positive impact upon environment, due to zero gas emissions and fuel use (Pendyala & Bhat, 2014; Zmud & Sener, 2017). The decrease in traffic and the number of car accidents due to human error are two more benefits from the use of these cars (Pendyala & Bhat, 2014; Zmud & Sener., 2017). One more potential benefit is that elderly people or people with low confidence may be able to use these cars (Pendyala & Bhat, 2014). The table below summarizes the main benefits of self-driving cars, which may constitute important motivation factors for their usage.

Table 6. Benefits of self-driving cars

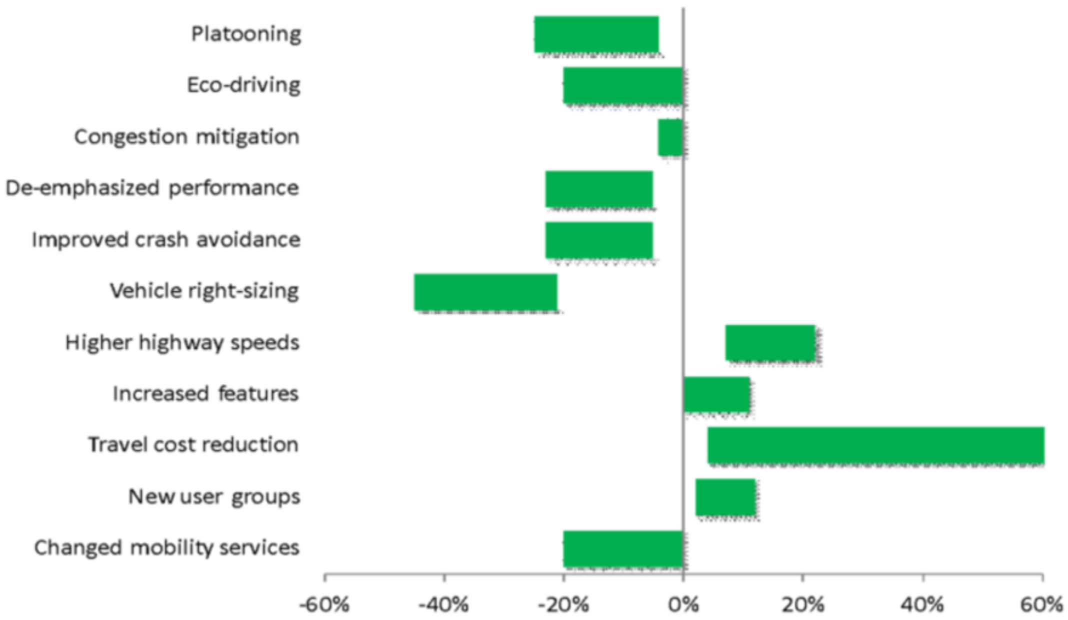
| Category | Details |
|---|---|
| **Zero emission** | - Optimization of traffic flow management<br>- Reduction of fuel energy<br>- Reduction of $CO_2$ emission |
| **Demographic change** | - Support unconfident drivers<br>- Enhance mobility for elderly people |
| **Vision zero** | - Potential for more driver support by avoidance of human driving errors |
| **Increasing traffic density and capacity** | - Optimization of traffic flow management<br>- Convenient, time efficient driving via automation<br>- Optimization of route choice, passage through intersections, and navigation through and around work zones<br>- Positive impact on community and regional planning and urban design |
| **Economy** | - Ensure unique selling proposition<br>- Attractive products by technological leadership |
| **Maturity of driver assistance systems** | - Sensors are approved and cost-effective<br>- Actuators in series production |

| | |
|---|---|
| **Safety** | - Enhanced vehicle control, positioning, spacing, and speed harmonization<br>- No drowsy drivers, impaired drivers, stressed drivers, or aggressive drivers |

Source: Pendyala and Bhat, 2014

Self-driving cars can contribute to the reduction of greenhouse gas through the optimization of vehicle's route, and the reduction of traffic (Casley et al., 2013), as well as the reduction of fuel consumption (Litman, 2017). Apart from this, the type of fuel autonomous cars will use can also result in the reduction of gas emissions. In fact, it is estimated that these cars are going to reduce carbon emissions by 200 million tons of $CO_2$ only in the USA (Deutsche Welle, 2016). The Intelligent Transportation Society of America predicts that the intelligent transportation systems could achieve a reduction in oil consumption and related greenhouse gas emissions of about 2-4% each year until 2014 (Pyper, 2014). The following figure depicts the positive and negative impacts of self-driving cars on energy consumption.

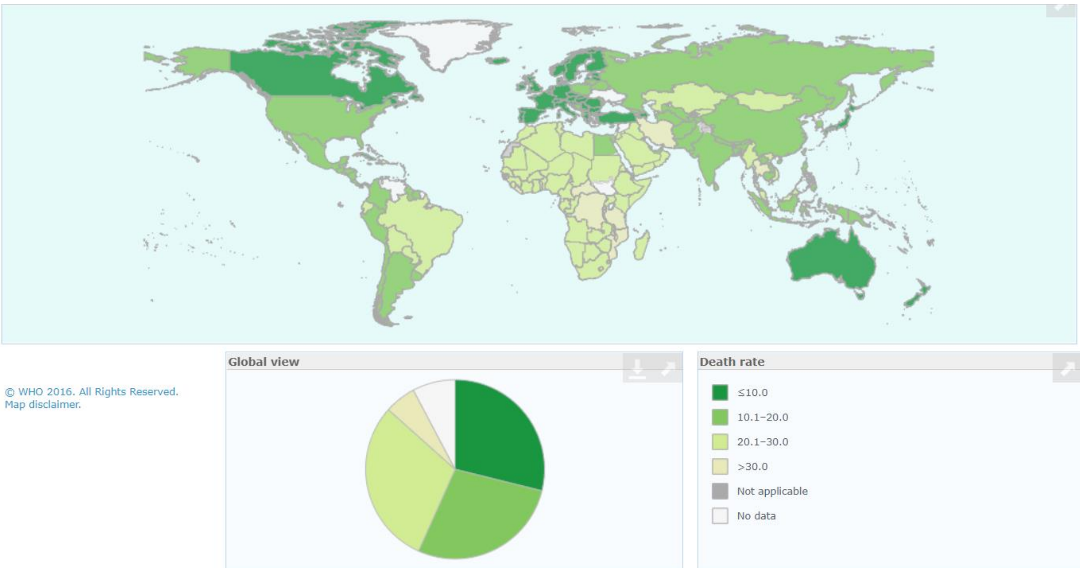
Figure 15. Percentage of changes in road transport energy consumption due to vehicle consumption




Source: Wadud, 2016

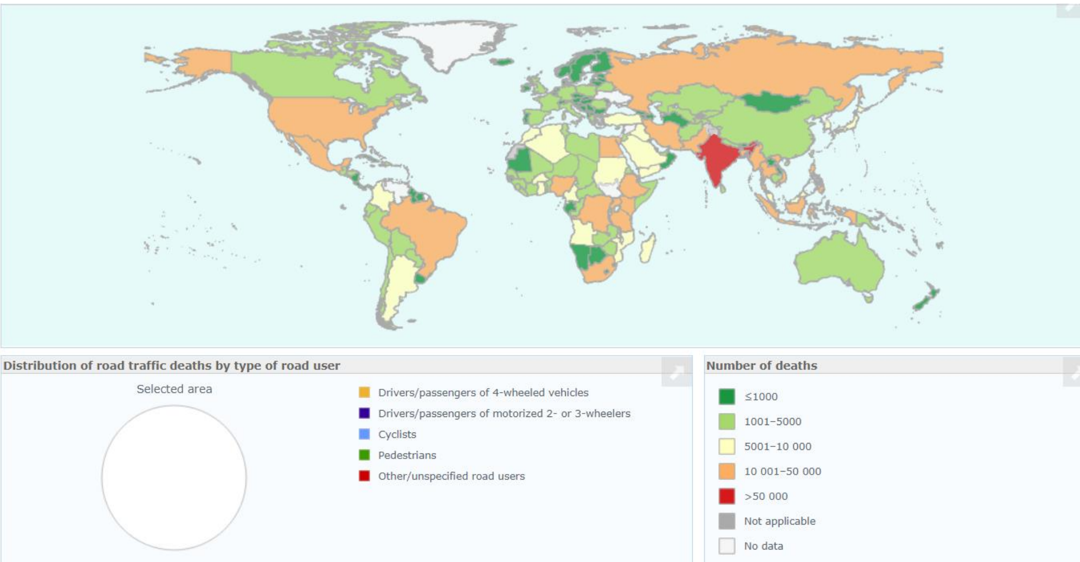
Some of the above features, however, is a controversial issue. Safety, for example, falls into this category. In 2013 there were 1.25 million deaths related to road traffic. At the same year, the fatality of traffic-related accidents was higher in low- and middle-income countries, as depicted in Figure 4 (WHO, 2013), which is translated to economic losses up to 5% of the GDP (WHO, 2015). At an international level, during the time period 2010-2013 there was a decrease of road traffic deaths in 79 countries and an increase in 68 countries (WHO, 2015). Motorcyclists, cyclists and pedestrians, who are among those with the least protection, account for almost half of the road traffic deaths, as depicted in Figure 5 (WHO, 2013). Overall, road traffic injuries are the primary cause of death for people between 15 and 29 years old, and the ninth cause of death among all age groups globally, whereas it is estimated that until 2030 it will be the seventh cause of death across all age groups worldwide (WHO, 2015).

Figure 16. Estimated road traffic death rate, 2013




Source: WHO, 2013

Figure 17. Number of road traffic deaths and distribution by type of road user, 2013




Source: WHO, 2013

Within the framework of mobility, Rashid et al. (2017) used IoT in order to examine and prove than in the case of a smart city, the application of this technology can facilitate the mobility of people with disabilities. The technologies used by the researchers were Augmented Reality and RFID. The system proposed by Rashid et al. (2017) is an interactive AR application which can run on different interfaces, allowing the user to interact digitally with the physical objects he / she wants, due to an updated stock provided by an RFID system. RFID technology provides significant advantages as it can detect individual objects without direct visual contact, as well as hidden objects (Rashid et al., 2017). Through this technology, reliable and inexpensive location-based systems allow real-time representation of real-time 3D maps, and thus the use of augmented reality scenarios (Santos et al., 2017).

Amsterdam is an innovative city and within this framework it tries to makes mobility easier, along with improving the safety, air quality, quality of life, and attractiveness of the city. For this reason the city has implemented the Action Program Smart Mobility 2016-2018, which has the following objectives (Amsterdam City, 2017):

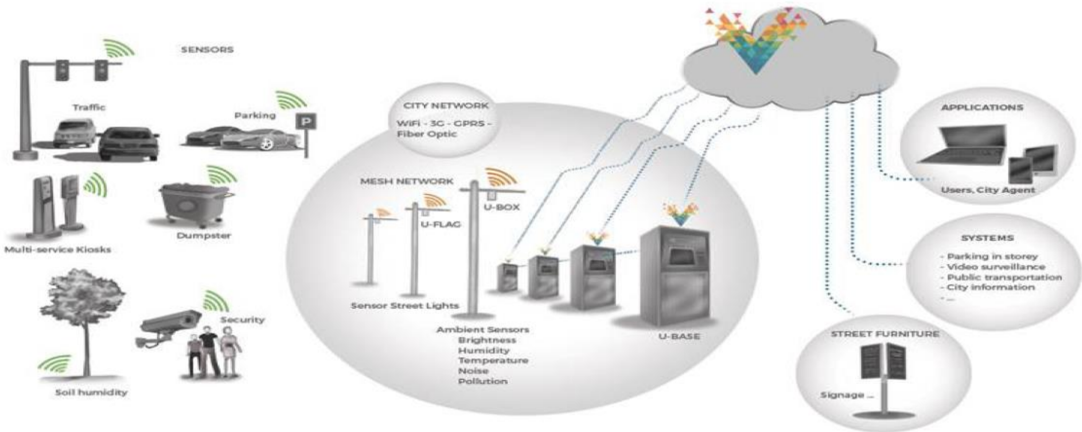
1. "Get insights in (technological) developments and innovations in the field of mobility and its impact on the city.
2. Anticipate on technological innovations and use these to reach the goals.
3. Stimulate and accelerate innovation in the city
4. Strengthen cooperation with knowledge institutions and market parties.
5. Become smarter as a municipality by working data driven with knowledge institutions and market parties. Condition is to protect privacy and sensitive information more and better. This program needs to work on mobility solutions for Amsterdam. Clean Air is important, but is a bigger topic in the Agenda Sustainability".

### 2.2.2 Smart traffic

In their study, Adisesha et al. (2017) propose a model for smart traffic. The elements of this model, which is depicted in the figure below, are the following:

- Smart parking services: these services on the one hand will prevent illegal parking and on the other will facilitate parking process. This will be achieved through the construction of a platform which will allow real-time checking of available space and parking prices in areas that require parking and facilitation of reservation/payment through Web and mobile connections.
- Citizen participation-oriented illegal parking prevention services: citizens will have the ability to report cases of illegal parking by using their smart phones.
- Smart safe crosswalk service: this service will help in the prevention of both car and pedestrian accidents, through the detection of pedestrians in children protection zones and through the alert of both pedestrians and approaching vehicles through electronic display boards

Figure 18. Smart Traffic Service




Source: Adisesha et al., 2017, p. 143

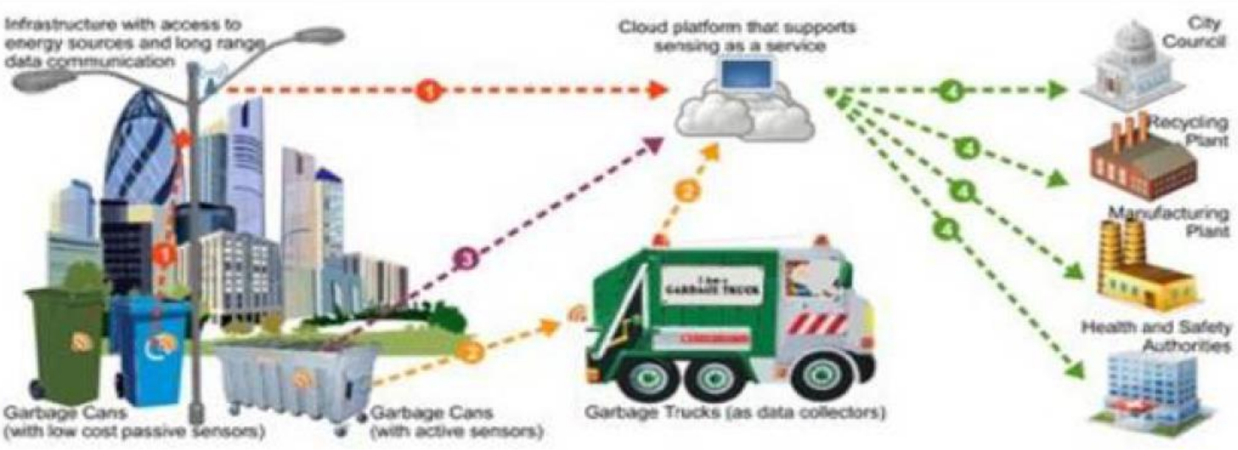
One more example in the context of smart traffic is the virtual traffic manager in Amsterdam, according to which traffic is managed automatically. Currently there are three traffic managers: the municipality of Amsterdam, the province of North Holland and the national government. The problem that existed was that in some cases the orders from these managers were conflicting. In order to solve this problem, Amsterdam used Technolution's Mobimaestro system, which is connected to the traffic system of the national government. The result is that both centers can monitor the traffic and automatically manage it. So far the outcome of this program is a 10% reduction in vehicle loss hour. Future prospects include the connection of the smart traffic management system with in-car and navigation equipment (Amsterdam City, 2017).

Apart from this, Amsterdam has implemented Practical Trial, which aims to improve the traffic flow and reduce the tragic congestion, along with environmental sustainability. Even though it is an experiment, it is expected to test whether it is possible a scenario where cars, navigation systems, traffic lights and information signs are connected and automatically working (Amsterdam City, 2017). Concerning the issue of traffic, San Fransisco has introduced a program for smart parking at a pilot level. According to the first estimations, the amount of time spending for searching a parking was reduced by 43%. A similar project was implemented in the city of Nice in France across 8,500 on-street spaces and 19 multi-storey parking structures in 2013 and the results were the following: operational parking costs reduced by 30 per cent, there was a 24 month return on investment, while at the same time congestion and pollution reduced by 10 per cent (IoT Alliance Australia, 2016).

### 2.2.3 Smart energy

Last but not least, within the concept of smart energy, the smart garbage and waste management should be briefly mentioned. Adisesha et al. (2017) describe this smart ability, suggesting that IoT may exploit sensor data collected via sensors that are located in the cities. The researchers propose an algorithm concerning waste management fleet, and more precisely an algorithm that can addresses the following issues of trucks used in garbage collection: overloaded or damaged truck. According to the model proposed by the researchers, waste collection will be made based on two types of trucks: the Low Capacity Trucks (LCTs) and the High Capacity Trucks (HCTs). Especially the second type of trucks allow the reduction of the route trips to the dumps, since these trucks are characterized by increased storage capacity. The result is that garbage and waste management is more cost efficient. This model is depicted in the figure below.

Figure 19. Smart Waste Management System



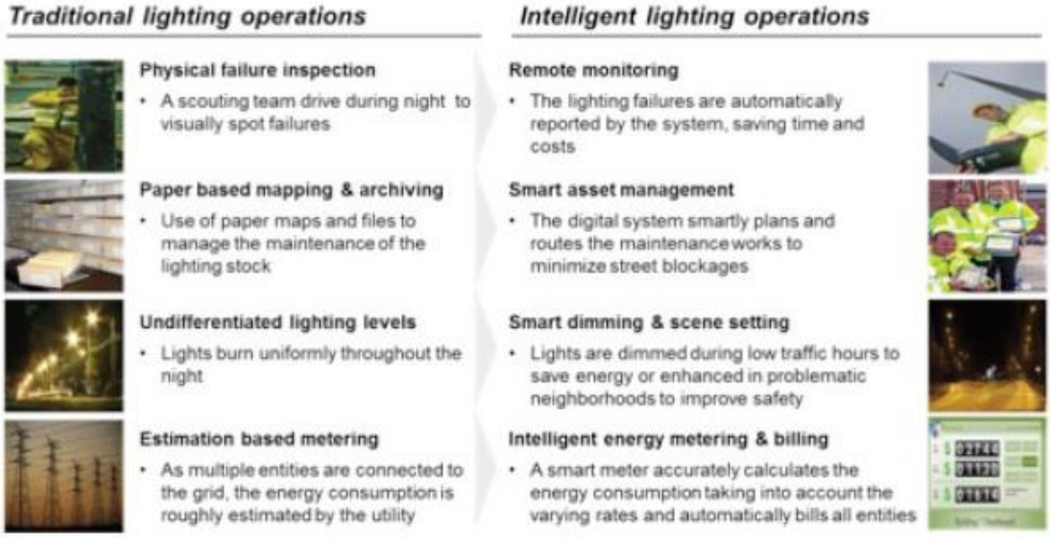

Source: Adisesha et al., 2017, p. 144

One more example of smart energy is the smart street lighting. Street lights consume nearly the half (40%) of a city's electricity costs. Within this framework, some cities have developed smart street lighting schemes through the use of LEDs. Some of these cities are the following (Smart Cities Council, 2015):

- Los Angeles, USA: the city replaced more than 150,000 street lights with LEDs, which resulted in a reduction in energy usage more than 63% and in the electricity cost about $7 million each year
- Edmonton, Canada: energy use and maintenance reduction has been achieved through the street light replacement with LEDs in 39 neighborhoods
- Peterborough, United Kingdom: the city has replaced 400 street lights with LEDs, which resulted in 50% reduction in energy use and in $CO_2$ emissions by 27 tons each year.
- Boston, USA: until the end of 2012 the city had replaced almost 40% of its street lights with LEDs, which means a reduction of $2.8 million each year in electricity cost, along with the reduction in maintenance costs.
- Madrid, Spain: 225,000 street lights have been / will be replaced. The investment will be funded through the savings in the electricity costs, as it is expected that the project will result in a reduction of 44% in energy consumption

In general, the future of street lighting is digital, from fluorescent lightbulbs to solid-state lighting, all connected to an energy grid through a variety of last-mile access technologies, as it can be seen from the following figure.

Figure 20. Moving from “Traditional” to “Intelligent” Lighting Networks



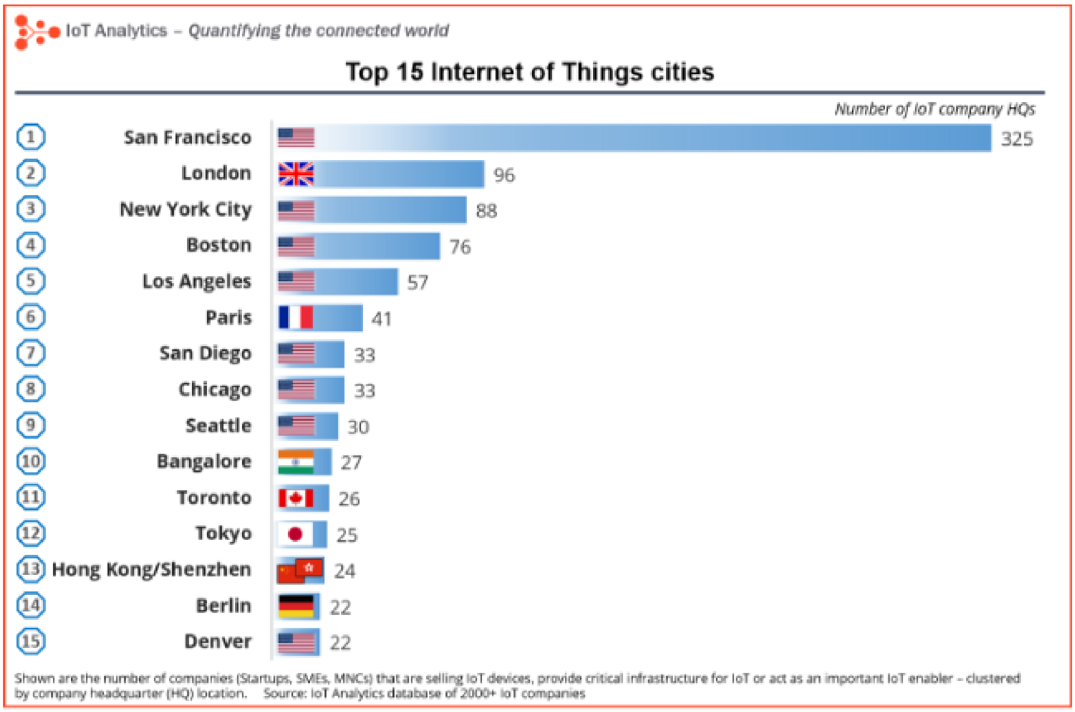

Source: Mitchell et al., 2013, p. 6

Similarly, the City of Sydney replaced 6,450 conventional lights with LEDs and the result was the saving of almost $800,000 a year in electricity bills and maintenance costs (IoT Alliance Australia, 2016). Apart from the use of LEDs in street lights, San Diego was the first city in the USA to implement the GE’s LightGrid technology, according to which street lights are remotely tuned, so as to provide light only when needed. In the United Kingdom, light stands are considered as Wi0Fi access points, which will allow the provision of internet services in rural and remote areas. In addition, there are thoughts of implementing sensors to street lights, in order to allow researchers to collect and analyse data that could be useful in the improvement of environmental and weather monitoring, traffic patterns (as in the case of Chicago), public safety (for example through noise and movement detection as in the case of Glascow, or through preventing drug abuse and candalism as in the case of Ottawa, or through a lighting system that can broadcast sound for pedestrians’ alert as in the case of Las Vegas), lighting and parking (Smart Cities Council, 2015)

**2.3 IoT cities**

Based on the IoT Analytics database of 2000+ IoT companies, the top 15 emerging Internet of Things cities are depicted in the figure below.

Figure 21. Top 15 IoT cities




Source: Lueth, 2015

1. San Francisco / Bay Area (Silicon Valley): more than 300 headquarters of companies operating in IoT are located in this city. There are both small star-ups and some of the top 20 Internet of Things companies such as Google, Apple, or Cisco (Silicon Valley). In addition, this city is the base for Semiconductor companies such as Atmel, sensor manufacturers such as Invensense, or analytics providers such as Splunk. The emphasis of these companies is given upon consumer IoT applications instead of business-related IoT applications.

2. London, UK: this city is the base of the popular IoT platform Everything or the minicomputer Raspberry Pi. In addition, this city has a traditional strong footprint in Telco and M2M.

3. New York City, NY, USA: even though there are not large multinational IoT companies located in this city, there are several start-ups and rising companies, such as the Quirky/Wink smart home solution or the Canary security system.

4. Boston, MA, USA: this city's innovation spirit is based on its human capital, since it is the base of high-ranking universities worldwide, such as MIT and Harvard. For this reason, there are several innovative IoT-related companies in this city, such as Predictive analytics company RapidMiner or MC10 Inc., a pioneer in wearable electronics.

5. Los Angeles, CA, USA: similar to Boston, LA Is the base for companies operating in the field of wearable devices. More than 50% of IoT-related companies are located in LA specialized in this field, when the average of other cities is around 15%. One of the most well-known company is the "Puls" by the singer "Will I am", whereas there are also some start-ups, such as Trakdot or Daqri.

6. Paris, France: More than 50% of IoT-related companies are located in this city. In addition, companies located in Paris offer quite a few IoT platforms that promise to allow connectivity for your things (e.g., Beebotte, Sen.se, Weio).

7. San Diego, CA, USA: Compared to San Francisco and LA, IoT-related companies located in this city place much more emphasis on business-related applications. Some strong examples are the companies General Atomics, Qualcomm, Novatel Wireless, or Systech.

8. Chicago, IL, USA: this city has attempted to "become the most digitally connected city in the world". For this reason it hosted the Internet of Things World Forum in 2014. In addition, this city has several connected health and smart grid companies. The most promising start-up is TempoIQ, a real-time database built specifically for the Internet of Things.

9. Seattle, WA, USA: this city is in this list because it is the base of Amazon and Microsoft. In addition, this city is the location of several IoT-related companies, such as the industrial IoT startup Seeq and the connected car platform Airbiquity.

10. Bangalore, India: this city is known as "Silicon Valley of India", since in this city several IoT-related start-ups are located, which are very promising in the field of IoT platforms, such as Altiux or ConnectM. In addition, in this city there is also the well-known company Wipro, which is the large multi-billion IT solution integrator.

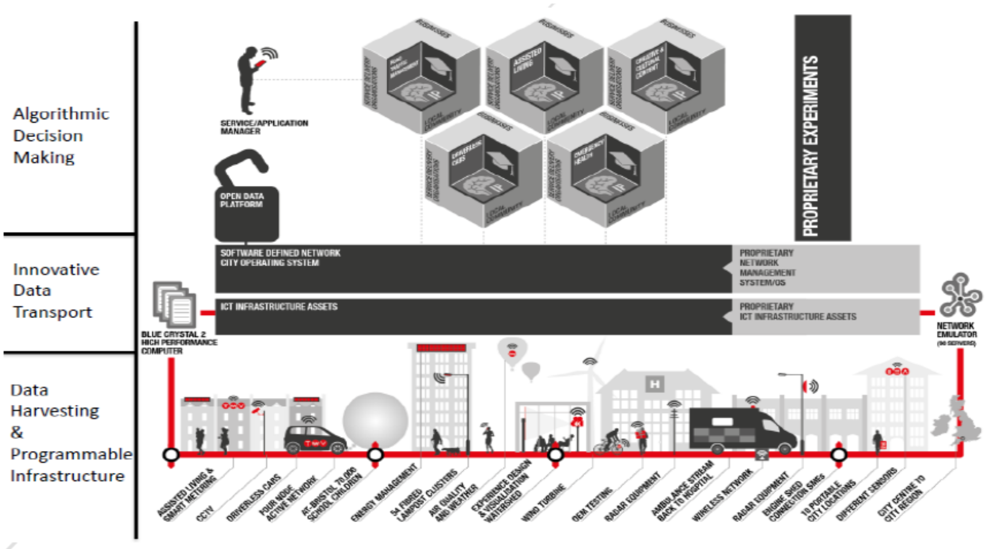
Apart from the above cities, there are also several examples of smart city applications in various cities of Mexico, as follows (Cartajena, 2016):

1. Santiago: Automating pricing depending on traffic
2. Mexico DF: Smart and eco buildings
3. Bogota: Electrical and eco Subway
4. Buenos Aires: Public Wi-Fi and public tech job programs
5. Rio de Janeiro: Weather, Crime, Traffic & Emergency Monitoring
6. Curitiba: Considered the most ecological City
7. Medellin: Considered the most innovative City

8. Montevideo: University and educational programs to create human capital

Bristol is another example of smart city, due to the program 'Bristol Is Open', which is a joint venture between the University of Bristol and Bristol City Council. In this program, both data sensors and smart city technologies are used, in order to better manage and respond in real-time to its daily operations of the city across traffic congestion, waste and energy management. These networks are controlled in a Software Defined Network that is based on the OpenFlow standard.

Figure 22. City Experimentation as a Service in Bristol




Source: IoT Alliance Australia, 2016, p. 6

In order for a city to be considered as smart city, there are several elements that should be examined, assessing its IoT adoption readiness. These elements are ICT skills, ICT infrastructure, ICT education, favourable institutions, sophisticated markets, competitiveness and enabling environment. Using these elements, numerous indeces have been developed, such as Network Readiness Index, ICT Development Index, Global Innovation Index, Global Competitiveness Index and Knowledge Economic Index. The following table depict the top ten of countries that are network ready, based on region. As it can be seen, advanced countries (AE) have a higher average, followed by countries in Middle East and North Africa (MENA), Latin America and the Caribbean (LAC), Emerging and Developing Asia (EDA), and finally Sub-Saharan Africa (SSA).

Table 7. Top 10 Network Ready Countries per Region

| SSA | | | MENA | | | EDA | | | LAC | | | AE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score |
| 45 | Mauritius | 4.5 | 23 | UAE | 5.3 | 32 | Malaysia | 4.9 | 38 | Chile | 4.6 | 1 | Singapore | 6 |
| 74 | Seychelles | 4.0 | 27 | Qatar | 5.1 | 61 | Mongolia | 4.2 | 39 | Barbados | 4.6 | 2 | Finland | 6 |
| 75 | South Africa | 4.0 | 30 | Bahrain | 4.9 | 62 | China | 4.2 | 46 | Uruguay | 4.5 | 3 | Sweden | 5.8 |
| 83 | Rwanda | 3.9 | 35 | Saudi Arabia | 4.7 | 65 | Sri Lanka | 4.1 | 49 | Costa Rica | 4.4 | 4 | Netherlands | 5.8 |
| 86 | Kenya | 3.8 | 42 | Oman | 4.5 | 67 | Thailand | 4 | 51 | Panama | 4.4 | 5 | Norway | 5.8 |
| 87 | Cape Verde | 3.8 | 52 | Jordan | 4.3 | 76 | Philippines | 4 | 64 | Colombia | 4.1 | 6 | Switzerland | 5.7 |
| 101 | Ghana | 3.5 | 72 | Kuwait | 4 | 79 | Indonesia | 3.9 | 69 | Mexico | 4 | 7 | United States | 5.6 |
| 102 | Namibia | 3.5 | 78 | Morocco | 3.9 | 85 | Vietnam | 3.9 | 70 | Trinidad and Tobago | 4 | 8 | United Kingdom | 5.6 |
| 104 | Botswana | 3.4 | 81 | Tunisia | 3.9 | 88 | Bhutan | 3.7 | 80 | El Salvador | 3.9 | 9 | Luxembourg | 5.6 |
| 106 | Senegal | 3.3 | 94 | Egypt | 3.6 | 89 | India | 3.7 | 82 | Jamaica | 3.9 | 10 | Japan | 5.6 |
| AVERAGE | | 3.8 | AVERAGE | | 4.4 | AVERAGE | | 4.1 | AVERAGE | | 4.2 | AVERAGE | | 5.8 |

Source: Atayero et al., 2016, p. 3

Since ICT is important element in IoT and is used in order to assess network readiness, the following table depicts the top ten ICT developed countries by region. As it can be seen, the Europe regions has the highest average, followed by Asia and the Pacific (A&P), The Americas, Middle East and North Africa (MENA), Commonwealth of Independent States (CIS) and Sub-Saharan Africa (SSA) in the last position.

Table 8. Top 10 ICT Developed Countries per Region

| SSA | | | MENA | | | A&P | | | CIS | | | The Americas | | | Europe | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score |
| 70 | Mauritius | 5.22 | 27 | Bahrain | 7.40 | 2 | South Korea | 8.85 | 38 | Belarus | 6.89 | 14 | United States | 8.02 | 1 | Denmark | 8.86 |
| 75 | Seychelles | 4.97 | 32 | UAE | 7.03 | 9 | Hong Kong, China | 8.28 | 42 | Russia Fed. | 6.70 | 23 | Canada | 7.62 | 3 | Sweden | 8.67 |
| 90 | South Africa | 4.42 | 34 | Qatar | 7.01 | 11 | Japan | 8.22 | 53 | Kazakhstan | 6.08 | 35 | Barbados | 6.95 | 4 | Iceland | 8.64 |
| 93 | Cape Verde | 4.30 | 47 | Saudi Arabia | 6.36 | 12 | Australia | 8.18 | 61 | Moldova | 5.72 | 48 | Uruguay | 6.32 | 5 | United Kingdom | 8.50 |
| 104 | Botswana | 4.01 | 52 | Oman | 6.1 | 16 | Singapore | 7.90 | 64 | Azerbaijan | 5.65 | 54 | St. Kitts and Nevis | 6.01 | 6 | Norway | 8.39 |
| 113 | Ghana | 3.46 | 62 | Lebanon | 5.71 | 19 | New Zealand | 7.82 | 73 | Ukraine | 5.15 | 55 | Costa Rica | 5.92 | 7 | Netherlands | 8.38 |
| 117 | Namibia | 3.24 | 87 | Jordan | 4.62 | 22 | Macao, China | 7.66 | 74 | Armenia | 5.08 | 56 | Chile | 5.92 | 8 | Finland | 8.31 |
| 121 | Zimbabwe | 2.89 | 89 | Egypt | 4.45 | 66 | Brunei Darussalam | 5.43 | 78 | Georgia | 4.86 | 57 | Antigua & Barbuda | 5.89 | 10 | Luxembourg | 8.26 |
| 124 | Kenya | 2.79 | 96 | Morocco | 4.27 | 71 | Malaysia | 5.20 | 108 | Kyrgyzstan | 3.78 | 59 | Argentina | 5.8 | 13 | Switzerland | 8.11 |
| 126 | Gabon | 2.66 | 99 | Tunisia | 4.23 | 81 | Thailand | 4.76 | 115 | Uzbekistan | 3.40 | 65 | Brazil | 5.5 | 15 | Monaco | 7.93 |
| AVERAGE | | 3.80 | AVERAGE | | 5.72 | AVERAGE | | 7.23 | AVERAGE | | 5.33 | AVERAGE | | 6.40 | AVERAGE | | 8.41 |

Source: Atayero et al., 2016, p. 5

Innovation is the core element of a smart city. Within this framework, the Global Innovation Index is used in order to capture innovation outcomes, along with the factors that facilitate these deliveries. These factors include: the institutional environment for innovation to thrive, the level of human capital intensity, infrastructure, the degree of competition, freedom of enterprise, availability of and access to investment funds, and the extent to which businesses are knowledge-driven. The following table depicts the top ten innovative countries per region according to this index per region. As it can be seen, again the Europe region has the highest average, followed by South East Asia (SEA) and The Americas. In the last two positions one can found Sub-Saharan Africa (SSA) and Central and Southern Asia (CSA).

Table 9. Top 10 Innovative Countries per Region

| SSA | | | SEA | | | CSA | | | Europe | | | The Americas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score |
| 49 | Mauritius | 3.92 | 7 | Singapore | 5.94 | 61 | Armenia | 3.73 | 1 | Switzerland | 6.8 | 5 | United States | 6.0 |
| 60 | South Africa | 3.75 | 11 | Hong Kong (China) | 5.72 | 73 | Georgia | 3.38 | 2 | United Kingdom | 6.2 | 16 | Canada | 5.6 |
| 65 | Seychelles | 3.64 | 14 | South Korea | 5.63 | 81 | India | 3.17 | 3 | Sweden | 6.2 | 37 | Barbados | 4.2 |
| 84 | Senegal | 3.10 | 15 | New Zealand | 5.59 | 82 | Kazakhstan | 3.13 | 4 | Netherland | 6.2 | 42 | Chile | 4.1 |
| 90 | Botswana | 3.05 | 17 | Australia | 5.52 | 85 | Sri Lanka | 3.08 | 6 | Finland | 6.0 | 51 | Costa Rica | 3.9 |
| 92 | Kenya | 3.02 | 19 | Japan | 5.40 | 106 | Iran | 2.84 | 8 | Ireland | 5.9 | 57 | Mexico | 3.8 |
| 94 | Rwanda | 3.01 | 29 | China | 4.75 | 109 | Kyrgyzstan | 2.80 | 9 | Luxembourg | 5.9 | 62 | Panama | 3.7 |
| 95 | Mozambique | 3.01 | 32 | Malaysia | 4.60 | 114 | Tajikistan | 2.75 | 10 | Denmark | 5.8 | 67 | Colombia | 3.6 |
| 98 | Malawi | 2.97 | 52 | Vietnam | 3.84 | 121 | Bhutan | 2.61 | 12 | Germany | 5.7 | 68 | Uruguay | 3.6 |
| 102 | Burkina Faso | 2.87 | 55 | Thailand | 3.81 | 122 | Uzbekistan | 2.59 | 13 | Iceland | 5.7 | 70 | Brazil | 3.5 |
| AVERAGE | | 3.23 | AVERAGE | | 5.08 | AVERAGE | | 2.91 | AVERAGE | | 6.00 | AVERAGE | | 4.20 |

Source: Atayero et al., 2016, p. 7

In order for a city to implement IoT-related solutions and applications, it should be innovation-driven, which requires increased competitiveness on behalf of the economy. This is assessed using the Global Competitive Index (GCI), which evaluates on the one hand the basic requirements for facilitating competitiveness, and on the other the factors that facilitate efficiency in both competitiveness and innovation. The basic requirements for facilitating competitiveness include strong institutions that enable freedom of enterprise, competitiveness and protection of intellectual property rights, physical and social infrastructure, as well as sound macroeconomic environment. Factors that facilitate efficiency in competitiveness include higher levels of education coupled with market opportunities as well as technological readiness. Within this framework, the following table depicts the top ten competitive economies per region. As it can be seen, one more time the Europe region has the highest average, while Asia and the Pacific region is at the second place. The countries following belong to the region of Middle East and North Africa (MENA), The Americas, Commonwealth of Independent States (CIS) and Sub-Saharan Africa (SSA).

Table 10. Top 10 Competitive Economies per Region

| SSA | | | MENA | | | A&P | | | CIS | | | The Americas | | | Europe | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score |
| 39 | Mauritius | 6.46 | 12 | UAE | 7.61 | 2 | Singapore | 8.07 | 38 | Azerbaijan | 6.47 | 3 | United States | 7.91 | 1 | Switzerland | 8.14 |
| 56 | South Africa | 6.21 | 16 | Qatar | 7.49 | 6 | Japan | 7.81 | 50 | Kazakhstan | 6.31 | 15 | Canada | 7.49 | 4 | Finland | 7.86 |
| 62 | Rwanda | 6.10 | 24 | Saudi Arabia | 7.23 | 7 | Hong Kong | 7.80 | 53 | Russia Fed | 6.24 | 32 | Puerto Rico | 6.63 | 5 | Germany | 7.84 |
| 74 | Botswana | 5.93 | 27 | Israel | 7.07 | 14 | Taiwan, China | 7.50 | 69 | Georgia | 6.03 | 33 | Chile | 6.57 | 8 | Netherlands | 7.79 |
| 88 | Namibia | 5.66 | 40 | Kuwait | 6.44 | 17 | New Zealand | 7.43 | 76 | Ukraine | 5.91 | 51 | Costa Rica | 6.31 | 9 | United Kingdom | 7.73 |
| 90 | Kenya | 5.61 | 44 | Bahrain | 6.40 | 20 | Malaysia | 7.37 | 82 | Moldova | 5.76 | 55 | Barbados | 6.23 | 10 | Sweden | 7.73 |
| 92 | Seychelles | 5.59 | 46 | Oman | 6.37 | 22 | Australia | 7.26 | 85 | Armenia | 5.73 | 57 | Brazil | 6.20 | 11 | Norway | 7.64 |
| 96 | Zambia | 5.51 | 64 | Jordan | 6.07 | 26 | South Korea | 7.09 | 91 | Tajikistan | 5.61 | 61 | Mexico | 6.10 | 13 | Denmark | 7.56 |
| 106 | Gabon | 5.34 | 72 | Morocco | 6.01 | 28 | China | 6.99 | 108 | Kyrgyzstan | 5.33 | 65 | Peru | 6.06 | 18 | Belgium | 7.40 |
| 107 | Lesotho | 5.33 | 79 | Algeria | 5.83 | 31 | Thailand | 6.66 | | | | 66 | Colombia | 6.04 | 19 | Luxembourg | 7.39 |
| AVERAGE | | 5.77 | AVERAGE | | 6.65 | AVERAGE | | 7.40 | AVERAGE | | 5.93 | AVERAGE | | 6.55 | AVERAGE | | 7.71 |

Source: Atayero et al., 2016, p. 9

Last but not least, one important element of innovation and therefore IoT adoption within the context of a smart city is knowledge. An economy should be knowledge-driven, given the fact that knowledge includes human capital capacity, innovation system, ICT infrastructure, institutional frameworks and economic incentives of an economy, which are assessed using the Knowledge Economy Index. The table below depicts the top ten knowledge-driven economies per region. Again, Europe is in the leading position, since this region has the highest average, followed by Asia and the Pacific (A&P), The Americas, Middle East and North Africa (MENA) and finally Sub-Saharan Africa (SSA).

Table 11. Top 10 Knowledge-Driven Economies per Region

| SSA | | | MENA | | | A&P | | | Europe | | | The Americas | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score | Rank | Country | Score |
| 62 | Mauritius | 5.52 | 25 | Israel | 8.14 | 6 | New Zealand | 8.97 | 1 | Sweden | 9.43 | 7 | Canada | 8.92 |
| 67 | South Africa | 5.21 | 42 | UAE | 6.94 | 9 | Australia | 8.88 | 2 | Finland | 9.33 | 12 | United States | 8.77 |
| 85 | Botswana | 4.31 | 43 | Bahrain | 6.9 | 13 | Taiwan, China | 8.77 | 3 | Denmark | 9.16 | 40 | Chile | 7.21 |
| 89 | Namibia | 4.1 | 47 | Oman | 6.14 | 18 | Hong Kong, China | 8.52 | 4 | Netherlands | 9.11 | 41 | Barbados | 7.18 |
| 103 | Cape Verde | 3.59 | 50 | Saudi Arabia | 5.96 | 22 | Japan | 8.28 | 5 | Norway | 9.11 | 46 | Uruguay | 6.39 |
| 107 | Swaziland | 3.13 | 54 | Qatar | 5.84 | 23 | Singapore | 8.26 | 8 | Germany | 8.9 | 51 | Costa Rica | 5.93 |
| 111 | Kenya | 2.88 | 64 | Kuwait | 5.33 | 29 | South Korea | 7.97 | 10 | Switzerland | 8.87 | 52 | Trinidad and Tobago | 5.91 |
| 113 | Ghana | 2.72 | 75 | Jordan | 4.95 | 48 | Malaysia | 6.1 | 11 | Ireland | 8.86 | 53 | Aruba | 5.89 |
| 114 | Senegal | 2.7 | 80 | Tunisia | 4.56 | 55 | Russian Fed. | 5.78 | 14 | United Kingdom | 8.76 | 58 | Jamaica | 5.65 |
| 116 | Zambia | 2.56 | 94 | Iran | 3.91 | 56 | Ukraine | 5.73 | 15 | Belgium | 8.71 | 60 | Brazil | 5.58 |
| AVERAGE | | 3.67 | AVERAGE | | 5.87 | AVERAGE | | 7.73 | AVERAGE | | 9.02 | AVERAGE | | 6.74 |

Source: Atayero et al., 2016, p. 11

## 2.4 Smart cities projects

Box 4. European Smart City development

| |
|---|
| Europe is home to many of the world's leading Smart City initiatives. This is not just because of the strict demands that the EU has made in regard to carbon reductions (80% by 2050) and sustainable production and consumption, but is also supported by the fact that the EU itself supports and funds a range of different initiatives relating to Smart Cities. In 2011, the European Commission launched the latest of these initiatives called Smart Cities and Communities in order to address the European cities' role in creating a more sustainable and energy-efficient future. The initiative focuses on five key elements of a Smart City: active buildings, energy supply technologies, smart energy grids, low-carbon mobility, and urban energy planning. In 2012, the European Commission launched yet another initiative: "Smart City and Communities European Innovation Partnerships". This initiative aims to pool European resources relating to Smart City developments in order to support the demonstration of energy, transport and ICTs in urban areas. The funding opportunities for new projects are substantial; in 2013 alone this initiative has been granted 365 million euros. |

Source: Copenhagen Cleantech Cluster, 2012, p. 16

### 2.4.1 Project ESPRESSO

The project ESPRESSO means systemic Standardisation aPRoach to Empower Smart citieS and cOmmunities. It forms a network of stakeholders and experts (SmaCStak) with a dedicated Smart City coordination group. The goal of this project is to share ideas, experiences, good practices, resources and explore potential collaborations through a virtual "collaboratorium". As it is stated in the official website of the project, "ESPRESSO wants to define the scope of the project by analyzing sectorial systems, defining use cases and test scenarios, and building a conceptual standardized interoperable framework by evaluating the current standards landscape including gap analysis, and design pilots, which will be used to run test scenarios with the project partner cities to make practical experiences with the currently available set of standards and technologies" (ESPRESSO, 2017). A significant key objective of this project is the identification of a collection of open standards that work well together ("conceptual standards framework"), which are suggested to contribute to the direction of a smart city, and the identification of potential gaps, problems and weaknesses in the current standards. This will be achieved through using a standardization criteria matrix and through the development of recommendations that concern the current SDOs for future consideration, along with CEN, CENELEC and international standardization organizations. The four objectives towards this direction are the following (ESPRESSO, 2017):

- "Overlapping and subsequent harmonization potential of standards across different SDOs,
- Coordination requirements on new standards or components between European bodies CEN-CENELEC-ETSI,
- Priorities for standardization activities within the various SDOs (OGC, ISO, etc.) and development of aligned roadmaps for SDOs and associated organizations,

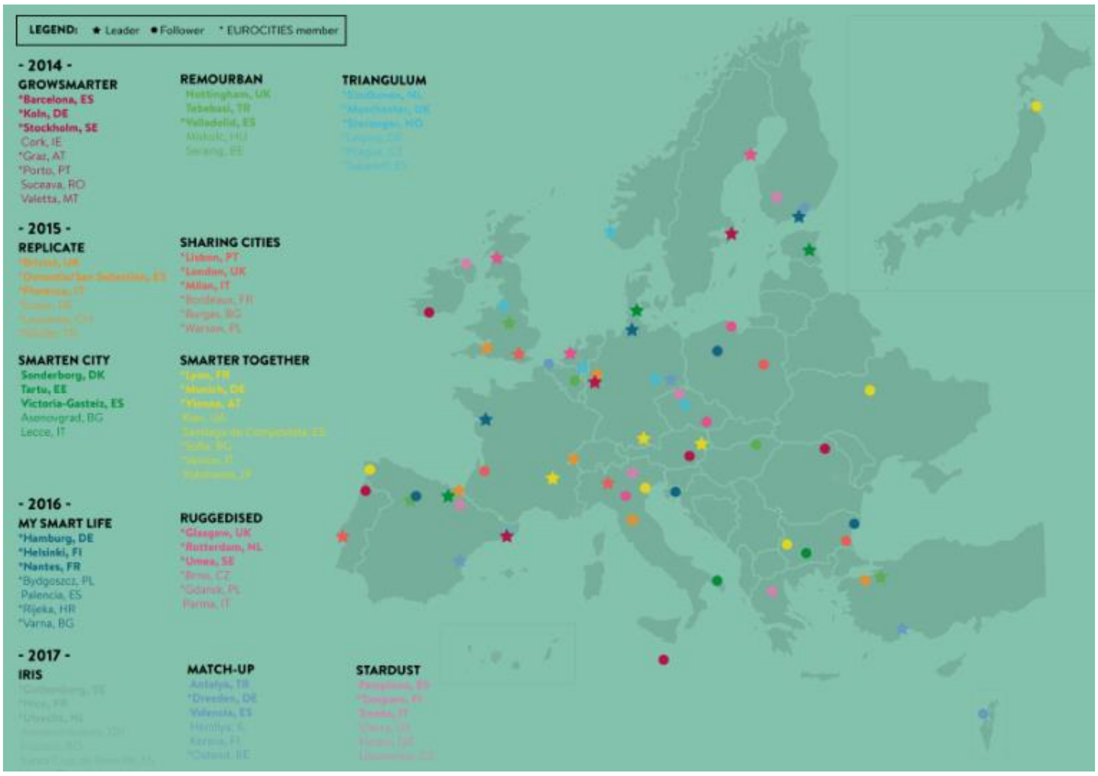
▪ Developments of fast-track guidelines for various SDOs.”

The overall goal of this project is the development of an Information and Business Framework. For this reason, this project develops a common language/shared vocabulary and a city information & indicator platform which can be adopted by a city,. In addition, a business framework will be developed which can be used by cities and industries as well as a strategic growth map for cites to assess their maturity. The standard protocols that will be developed will allow cities to make optimal use of smart city applications and these experiences will be shared across the network. Overall, the contribution of ESPRESSO is based on the development of innovative models and funding schemes (such as crowfunding), maturity models in the cities and optimal usage of the existing standards (ESPRESSO, 2017).

### 2.4.2 Sharing Cities project

Apart from ESPRESSO, there is also the Sharing Cities program, which aims at creating a common approach for smart cities, through international cooperation with European Innovation Partnership on Smart Cities and Communities, as depicted in the following figure.

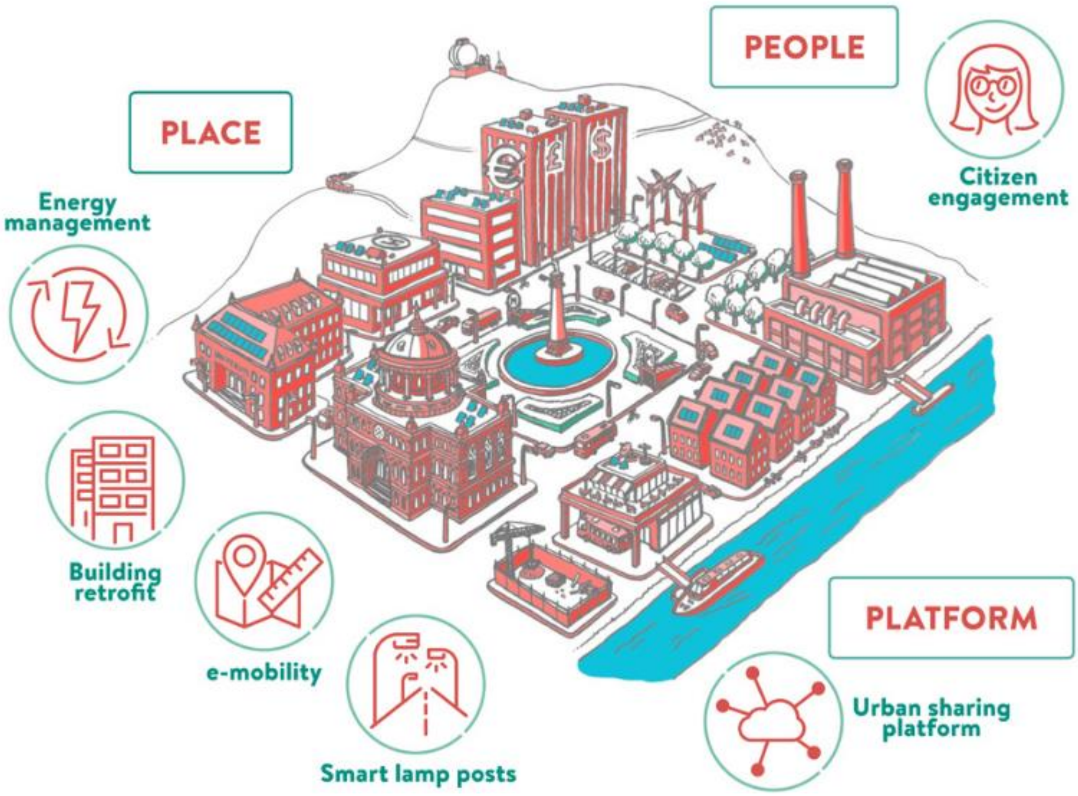
Figure 23. Cooperation in Sharing Cities Programme




Source: Sharing Cities, 2017

As it is stated in their official website, “the project seeks to develop affordable, integrated, commercial-scale smart city solutions with a high market potential […] Sharing Cities offers a framework for citizen engagement and collaboration at local level, thereby strengthening trust between cities and citizens” (Sharing Cities, 2017). The cities that are currently collaborating in this project are the following: the ‘lighthouse’ cities London, Greenwich, Lisboa, Milano, and the ‘fellow’ cities Bordeaux, Burjas and Warsaw. In fact, this program helps the cities to change their attitude and procedures, so as to facilitate the transition from city to smart city, incorporating smart city solutions and applications. The smart city solutions that are promoted through Sharing Cities Program are depicted in the following figure.

Figure 24. Smart city solutions of Sharing Cities Program




Source: Sharing Cities, 2017

So far, the Sharing Cities Programme has delivered publicly the following (Sharing Cities, 2017):

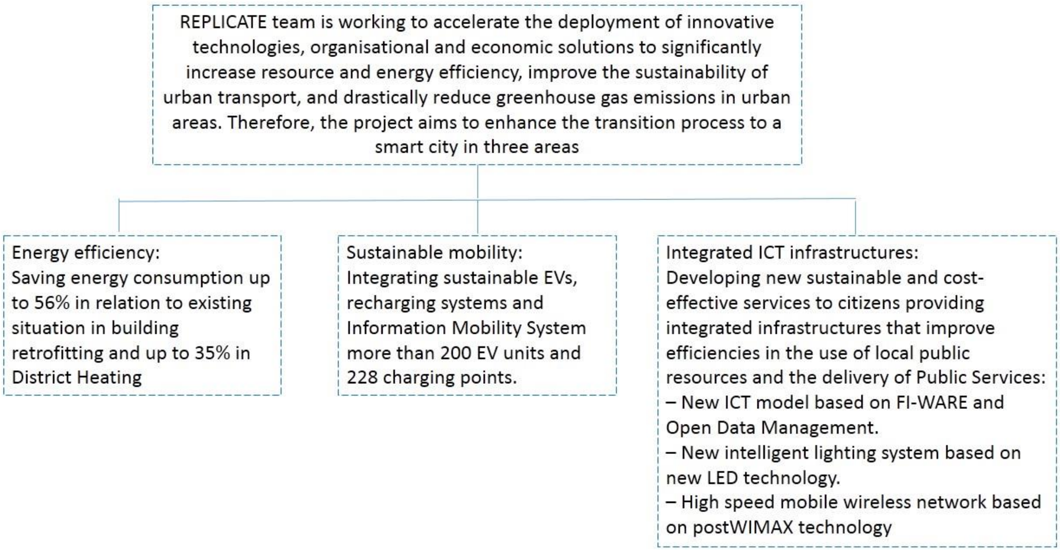
- D3.12 Demand Aggregation An Emerging Case Study The Humble Lamppost
- D4.6 Urban Sharing Platform Requirements
- D1.10 Sharing Cities consortium meeting minutes
- D3.9 Component based design
- D1.1 Minutes of the project meetings

- D1.2 Project Management Plan
- D1.3 Quality Assurance Plan
- D1.7 Risk management register
- D1.9 Minutes of the project meetings
- D2.1 Methods Book of existing and next stage customer insight and engagement methods
- D2.2 Report on Community Engagement Hubs
- D3.11 Installation of Smart Lampposts multi sensors to begin in the three demonstrator areas
- D4.2 Urban Sharing Platform Reference Model
- D5.1 One replication strategy
- D5.2 One two-day replication training
- D5.3 One replication training manual
- D5.4 Six city baseline reports
- D6.1 Leaflets (local languages)
- D6.2 Project logo and project graphic charter
- D6.4 Website
- D6.6 Communication Strategy
- D6.9 INEA common information and dissemination activities
- D7.1 Measures Exploitation Potential Report
- D7.4 Measure – Business Model Workshop
- D7.8 Funding London Model
- D8.1 Common Monitoring and Evaluation Framework

### 2.4.3 REPLICATE project

REPLICATE is one more project concerning smart cities. REPLICATE stands for REnaissance of PLaces with Innovative Citizenship And Technologies. Its vision is "to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens, and prove the optimal process for replicating successes within and across cities". There are three 'lighthouse' cities in the program, which are San Sebastian, Florence and Bristol, and three 'fellow' cities, which are Essen (Germany), Nilüfer (Turkey) and Lausanne (Switzerland). Energy, mobility and ICT solutions in cities are the core elements of this program. Within this framework, the objectives of the program are depicted in the following figure.

Figure 25. Objective of REPLICATE program



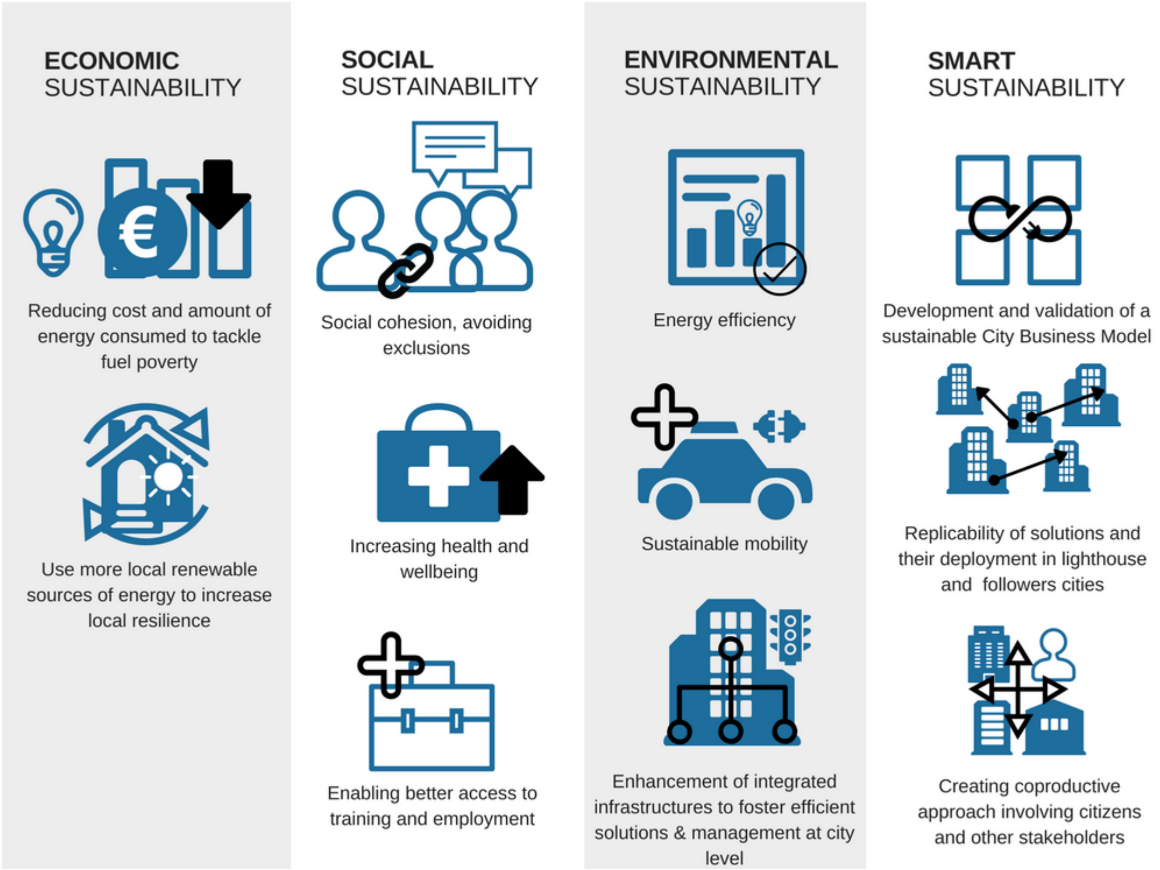

Source: REPLICATE, 2017

So far the project REPLICATE has some major main actions:

- In the context of energy efficiency, the actions of the project includes a) the Smart Grid and Demand Side Platform, b) the District Heating System, and c) the the Building Retrofitting in 696 dwellings and 34 commercial premises
- In the context of sustainable mobility, the actions of the project includes a) the acquisition / monitoring of 27 EV cars, 26 e-motos, 4 e-buses, 112 e-taxis, and 32 e-bikes, b) the advanced changing infrastructure, which consists of 256 charging points, and c) transport management services for citizens
- In the context of ICT and infrastructure, the actions of the project includes a) the Smart City Platform integrating local IT system and deployment of services and sensors, and b) the public smart lighting, which is a high speed wireless mobile network, deployment based on post IMAX technology

Overall, the program REPLICATE is committed to achieve economic, social, environmental and smart sustainability, as depicted in the figure below.

Figure 26. Commitments of REPLICATE program




Source: REPLICATE, 2017

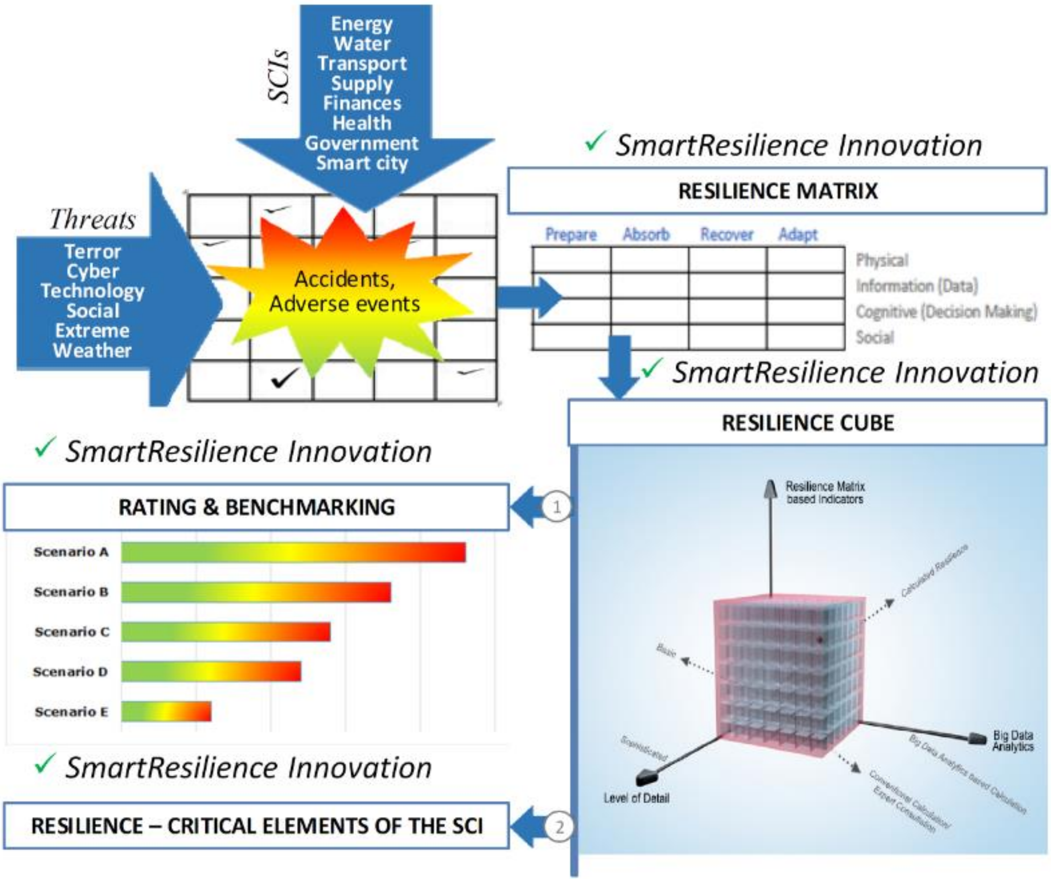
### 2.4.4 Smart Resilience project

One final project is the Smart Resilience project which "aims to provide an innovative "holistic" methodology for assessing resilience that is based on resilience indicators". The Smart Resilience specific objectives are listed below (Smart Resilience, 2017):

- "to identify existing indicators suitable for assessing resilience of SCIs
- to identify new "smart" resilience indicators (RIs) – including those from Big Data
- to develop advanced resilience assessment methodology and tools
- to test and validate the methodology/tools in 8 case studies, integrated under one virtual, smart-city-like, European case study dealing with energy, transportation, health, water infrastructures in smart cities, tackling also cascading effects"

The goal of this project is to improve the resilience of smart critical infrastructures, through the provision of an holistic methodology. It is expected that the project a) will foster new product development and solutions, generating new insights for SCI and their interdependencies, b) provide innovative tools and insights for rapid response planning, improved business continuity and organizational adjustments to become more resilient, and finally c) enhance resilience of the population based on concepts of increased awareness, preparedness, appropriate behavior during disasters. The framework of this project is depicted in the figure below.

Figure 27. Framework of Smart Resilience project




Source: Smart Resilience, 2017

**CHAPTER 3. SMART PARKING APPLICATIONS**

Nowadays even more smart parking applications are designed and developed in Greece and at international level. In this chapter some of these applications will be discussed, based on the characteristics and the features are mentioned in the official websites and in the website of Googleplay or Apple Store, where one can free download some of these applications.

**3.1 THESi (https://www.thesi.gr/)**

THESi is the new Controlled Parking System of the Municipality of Thessaloniki. It is one of the most advanced and integrated technology systems in Europe, with an on-line service-control-information-audience interface. THESi aims to facilitate a parking spot in the city, prevent illegal parking and all the problems it causes at the center of Thessaloniki and contribute to relieving the traffic problem. It concerns permanent citizens, visitors and people with disabilities. THESi provides free parking near the entrance of the house, with a specific mark and vehicle registration number, for each resident who belongs to one of the following three categories: a) Disabled person; b) Parent of child with disability; c) Judicial representative of a person with a disability. More precisely, THESi ensures:

• Free parking (blue stripe) for residents in their area.
• Visitor locations (white stripe) with a price exactly equal to parking time.
• Caring for fellow citizens and disabled people.
• Procedure without papers (scratch cards, phone cards, etc.).
• Easy parking through phone calls, SMS, app, internet and smart devices.
• Easy access to the vehicle's registration number as a "key" for each system operation (vehicle registration, parking, legality check).
• Purchase of parking time easily at one of the 400 points of sale (kiosks, mini market, OPAP agencies) with special marking.
• Possibility of proportional billing (per minute) and not pre-purchased parking time for registered users.
• Fast and effective control by the competent authority.
• Friendliness to foreign tourists as it is bilingual.
• Limitation of the traffic problem and the resulting pollution.
• Upgrading the quality of life.

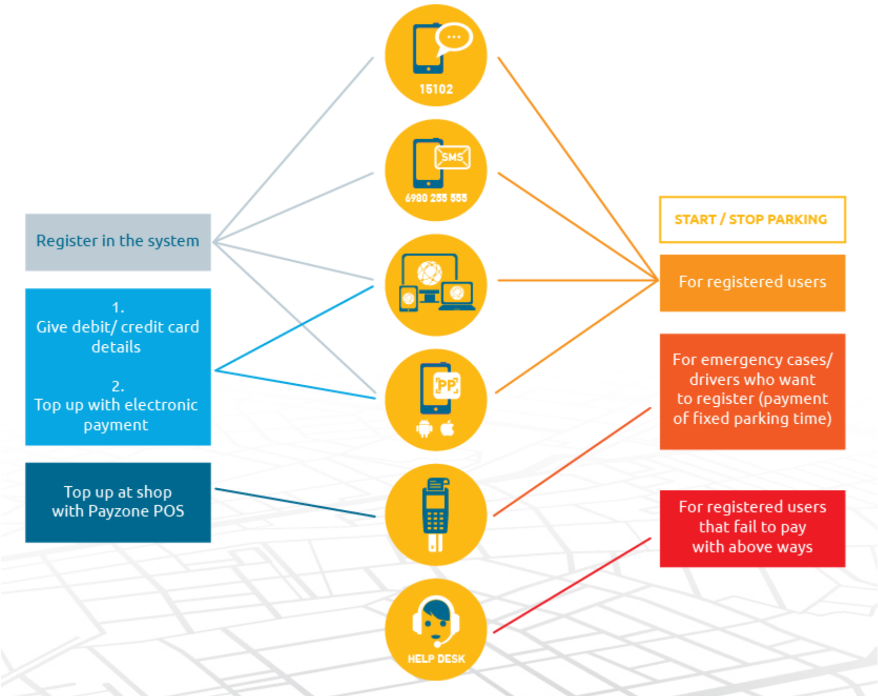
The registration to the controlled parking system is easy and simple, while it also provides significant benefits to the visitor-driver. Registration to THESi benefits the users because it offers:

• Multiple parking possibilities: a) using the ParkPal application, b) by phone call, c) sending SMS
• Parking charge per minute - Proxy charge
• History of parking times / locations
• Multi-vehicle parking

The application can be downloaded through Google Play and App Store. The webpage Myparkpal offers the ability to record and also manage the unique user account created after one signs up for it. Registration at myparkpal.gr is a prerequisite for using the parking service by phone or SMS. The registered user links his / her mobile number to his / her vehicle or vehicle registration number. So, THESi, the "smart" Controlled Parking System, recognizes this number either through a phone call, or through the ParkPal app, or by sending SMS. The parking procedure is then described by phone call and SMS.

Once one has registered in THESi, one can pay for the car's parking time in a visitor position with the electronic wallet, to which the user adds money using a credit or debit card or a prepaid ParkPal card that can be bought at one of the points selling. For each completed parking, the electronic wallet takes the exact amount of parking time declared each time THESi is used. SO, there is the ability for the user to pay through the Internet, smartphone/iphone or POS. If one is not registered in THESi, the user can easily pay for the parking time at the nearest 400 points of sale (kiosks, OPAP agencies, mini market) simply by stating the vehicle registration plate and the 5-digit field number parked and without having to return to the vehicle to leave a form of proof of payment.

Figure 28. Procedure followed in the application THESi




Source: https://www.thesi.gr/elegchomeni-stathmefsi-episkepton/diadikasia-eggrafis-leitourgias/?lang=en

However, the maximum parking time is four (4) hours. In addition, a prerequisite is to have enough rest to activate the parking for four hours, as one cannot set a duration of less than four hours in advance (no matter if one leaves earlier from the parking lot). If the amount in one's account is insufficient for four hours of parking then the only way to use it is through the ParkPal application. From the above, three challenges / disadvantages can be drawn as conclusion concerning the smart parking system THESi: a) the payment method; b) the limited maximum parking time; c) the protection of the personal data of the users.

### 3.2 Park in Athens (http://www.parkinathens.gr/)

PARKinATHENS is the City of Athens's Controlled Parking System, which has been implemented since November 2006 in Athens to improve the access of passing vehicles to the city's central traffic arteries (commercial triangle, Historic Center, etc.) and to facilitate the citizens / visitors in finding parking spaces. The operation of the system includes 12 total areas within the boundaries of the City of Athens and four basic categories of parking spaces for vehicles (visitors, permanent residents, special parking lots and bicycles). The application can be downloaded through Google Play and App Store. One can buy time for parking through the following ways: Mobile application of the City of Athens for easy & fast parking (myAthensPass), Pre-paid parking (POS) electronic cards, or scratched prepaid parking cards. The benefits of this application are the following:

- Easy parking via mobile phone or POS
- Provision of public space to pedestrians
- Reduction of the time spent finding a parking space
- Improvement of the accessibility of vehicles in the city
- Reduction of environmental pollutants
- Improvement of quality of life for all

**3.3 Parklot (**https://www.acer.com/ac/el/GR/content/acerdesign-smart-parking)

The Smart Parameter automatically indicates that a parking space is available and reports availability in the PKLOT application. Thus, the driver can quickly locate available parking spaces through the application. The triangular Smart Parameter automatically detects vehicles that park in on road side and use the identification of the license plate to charge automatically (via smartphone or POS). Moving systems have amazing interconnection, making it easy to switch from one place to another. This application functions only in Taiwan.

**3.4 Parkgene (**https://parkgene.io/**)**

Parkguru, the smart parking application is integrated into Parkgene, the world's first peer-to-peer parking application that uses blockchain technologies and cryptobay payments to bring even greater value to its users. Parkguru started in 2017 and in less than a year, since its launch in July 2017, it has gained more than 50,000 users by offering them the ability to find out where to park, reserve parking lot and pay by their mobile phone before even reach their destination. The application can be downloaded through Google Play and App Store.

In the context of the integration of the services it offers and through its subsidiary Parkgene, it has developed the world's first peer-to-peer parking service, enabling private parking space owners to rent it and receive payment in return in Gene Tokens (Parkgene's currency). In this way, through a renewed environment and additional tools such as Gene Wallet, all Parkguru users (now Parkgene) can not only park more easily and cheaper, but also gain revenue by renting their own parking space when is not occupied. The evolution of Parkguru and its incorporation in Parkgene, exploits the innovative technology of blockchain and cryptoinformation payments. Parkgene is the first peer-to-peer parking application in the blockchain, where application users can rent their private parking space, as with Airbnb, but for parking spaces. The new application contains 6 million parking spaces in 8,000 cities in the world, and there are more than 50 professional parking spaces and around 8,000 parking spaces in Greece, for which Parkgene users can pay via the Gene Wallet electronic wallet with cryptocoins Bitcoin, Ethereum, but also with the coin issued by Parkgene itself, the first Greek currency, the Gene token. At the same time, it is possible for all users to pay in conventional ways (cash, credit / debit card) in case they do not have cryptocoins.

### 3.5 ParkingRhino (https://www.parkingrhino.com/)

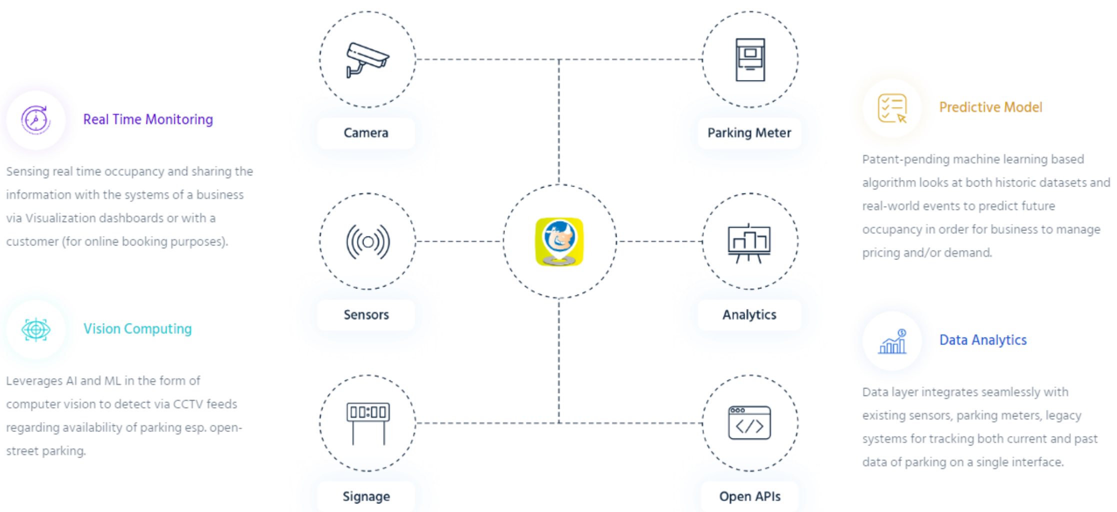
Full-stack IoT-based platform designed to solve parking problems for Smart cities. Disruptive parking management & discovery for urban commuters, parking lot operators & owners, city planners & administrators. It is a Smart Parking System using Mobile, IoT, Machine Learning, Artificial Intelligence and Big Data Analytics. The key features of the application are the following:

- Distinct markers for Free Parking, Paid Parking, Valet Parking & Event Parking
- Narrow or Broaden search for Parking locations by adjusting the radius of the search around the user's current mobile location
- Search for parking a given area by entering the area in the Search text box
- Tap on a given location to check the facilities for each location: Car Wash, Valet Parking, Covered parking, Car Charging etc.
- Real time navigation to the parking location
- Event information

ParkingRhino provides the user the following information about a parking location:

- Full address
- Photos of the location
- Distance from current location
- Total vehicle (car/park) parking capacity
- Hourly parking rates for weekdays as well as weekends
- Hours of operation for weekdays as well as weekends
- Availability of facilities for each location such as Car Wash, Valet Parking, Covered parking, Car charging etc.
- Happeninge places and event information in the users' city

Figure 29. Parking Rhino




Source: https://www.parkingrhino.com/

The Parkingrhino Data Dashboard Features are the following:

- Real-time monitoring: Real-time parking occupancy in each parking facility will be displayed in the dashboard of the management system, and will be updated in real time.
- Oversell analysis: Analyze the unique parking behavior associated with individual tenants/parking groups in an effort to make targeted oversell decisions based on each group's distinct usage patterns.
- Future projection: The system will analyze historical and real-time data to make predictions about future occupancy and revenue for up to 30 days in advance.
- Analytics: The system will give historical occupancy analysis, revenue analysis and duration analysis.

Based on the above smart parking systems discussed, one can see that the first advantage is the easiness in finding a parking lot, without the driver to try to find out a parking space for a long time-period. In addition, these applications can be downloaded from Google Play and App Store, meaning that they are compatible with both Android and Ios systems. Apart from these, they offer multiple payment methods. However, the major disadvantage is that they use personal data, raising concerns about the protection of users' data (e.g. name, address, card numbers).

## Chapter 4 Research Methodology

### 4.1. The method

Quantitative research using a questionnaire was used to fulfill the objectives of the research. Quantitative research was chosen as it enables the researcher to collect a large amount of data and examine the relationship that may have specific dimensions between them. More specifically, the general goal of the research is to investigate the views of citizens about the smart parking app. In particular, an attempt will be made to identify the answers to the following research questions.

1. What are the respondents' perceptions regarding the smart parking app?

2. Is there a statistically significant relationship between subjective norm, value for money and loyalty?

3. Are there any statistically significant differences on variable levels (subjective norm, value for money and loyalty) based on the demographics (Gender, age, ownership, time in town, parking, cost) of the respondents?

### 4.2. The Research Tool

The questionnaire includes six (6) introductory questions, nine (9) questions about the subjective norm, five (5) questions about value for money and finally six (6) questions about loyalty. The selection of questions was based on previous research efforts. The measurements of the questionnaire were made with various quantitative and qualitative scales, with the answers being given with a Likert scale of 5 points where 1 = I completely disagree and 5 = I completely agree.

**Reliability of the research tool**

The reliability of the research tool examines whether it is able to provide consistent findings (Easterby-Smith, et al., 2008). In particular, you examine whether the data collected serve the purpose of their collection, and will be answered if (Easterby-Smith et al., 2008):

1. Can the questionnaire yield the same results in repeated measurements?

2. Can the questionnaire yield the same or similar results if used by other researchers?

The reliability of the research instrument used for data collection was verified using the Cronbach Alpha index. The Cronbach alpha index is a measure of internal reliability and coherence (Gliem & Gliem, 2000). Following the audit, the Cronbach alpha showed a value of 0.934 for the subjective norm, 0.893 for the value for money dimension and 0.949 for the loyalty scale. In conclusion, the questionnaire can be considered reliable.

**Validity of the research tool**

Validity according to Saunders et al. (2009) refers to whether the findings are really relevant to those they intended to find. Structural validity refers in particular to research efforts with questionnaires to assess whether an individual or organization exhibits a particular trait (Fisher, 2010). The internal validity and reliability of the data collected and the response rate you achieve depend to a large extent on the design of the queries, and the structure of the questionnaire (Saunders et al., 2003). Specific specifications such as the following should be taken into account when designing the questionnaires (Saunders et al., 2003).

- The characteristics of the respondents
- The importance of approaching specific people
- The importance of the correct answers of the respondents (absence of answers)
- The size of the sample you need for the analysis
- The types of questions to be used
- The number of questions that will be used to collect the data

The validity of the content of the questionnaire for this research was ensured through careful selection and adoption of data from previously validated questionnaires (Dimitriadis & Kyrezis, 2011). In addition, the validity was verified through the pilot phase of the survey where the questionnaire was tested on citizens. The pilot test feedback was used to improve the readability and quality of the questionnaire questions.

**4.3. Participants**

The research population of this research effort was the citizens and the sample of the research was a sample of the ability of 90 people. The respondents were selected based on the researcher's ease of access to the population under study.

**4.4. Research process**

A pilot distribution of the questionnaire was considered as the appropriate way to check its content and structure as well as to verify its effectiveness as a tool through the resulting corrections. The pilot phase of the research was conducted in Thessaloniki on a sample of 3 people. In conclusion, the pilot survey did not present any problems and the questionnaire was deemed effective, well-designed and well-worded. In time the research was conducted from October 2019 to January 2020 and by the almost 90 citizens who agreed to participate in the research. Also, the completion of the questionnaire was done in the presence of the researcher, giving with this place the opportunity to answer questions and queries. Finally, all participants were informed that their participation was anonymous and that the results will be used only for the purposes of this dissertation.

### 4.5. Data analysis method

The statistical program SPSS was used for the processing of the questionnaires and the analysis of the data. Tables and diagrams were used to present the data, as well as statistical tests to answer research questions. In particular, analysis of variance (ANOVA), statistical test of independent samples (Independent Samples T-test) and statistical test Pearson Correlation were used. The selection of the statistical controls was made regarding the level of measurement of the variables and after checking the regularity of the distribution of the variables in each case.

## Chapter 5 Data Analysis

The current chapter presents the analysis of the research findings. The first section of the chapter includes the descriptive statistics analysis, while the second section the inferential statistics.

### 5.1. Descriptive Statistics

1. Gender

Table 1 and Figure 1 present the respondents answers regarding their gender. Specifically, the majority of the respondents were females (52.3%) while 47.7% were male respondents.

Table 11: Gender

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| | Male | 42 | 46.7 | 47.7 | 47.7 |
| | Female | 46 | 51.1 | 52.3 | 100.0 |
| | Total | 88 | 97.8 | 100.0 | |
| | N/A | 2 | 2.2 | | |
| Total | | 90 | 100.0 | | |

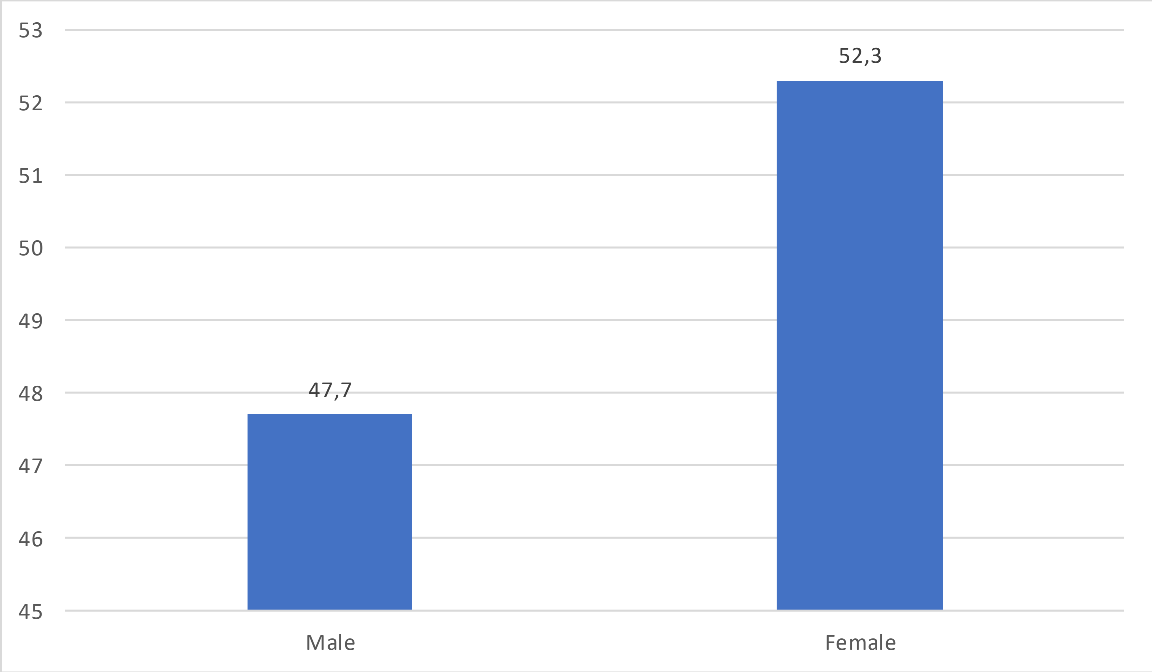


Figure 30 Gender

2. Age

Table 2 and Figure 2 present the respondents answers regarding their age. Specifically, the majority of the respondents were from 18 to 30 years old (51.1%) while 23.3% were from 31 to 40 years and 17.8% from 41 to 50 years old.

Table 12: Age

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| 18-30 | 46 | 51.1 | 51.1 | 51.1 |
| 31-40 | 21 | 23.3 | 23.3 | 74.4 |
| 41-50 | 16 | 17.8 | 17.8 | 92.2 |
| 51-60 | 6 | 6.7 | 6.7 | 98.9 |
| Over 60 | 1 | 1.1 | 1.1 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

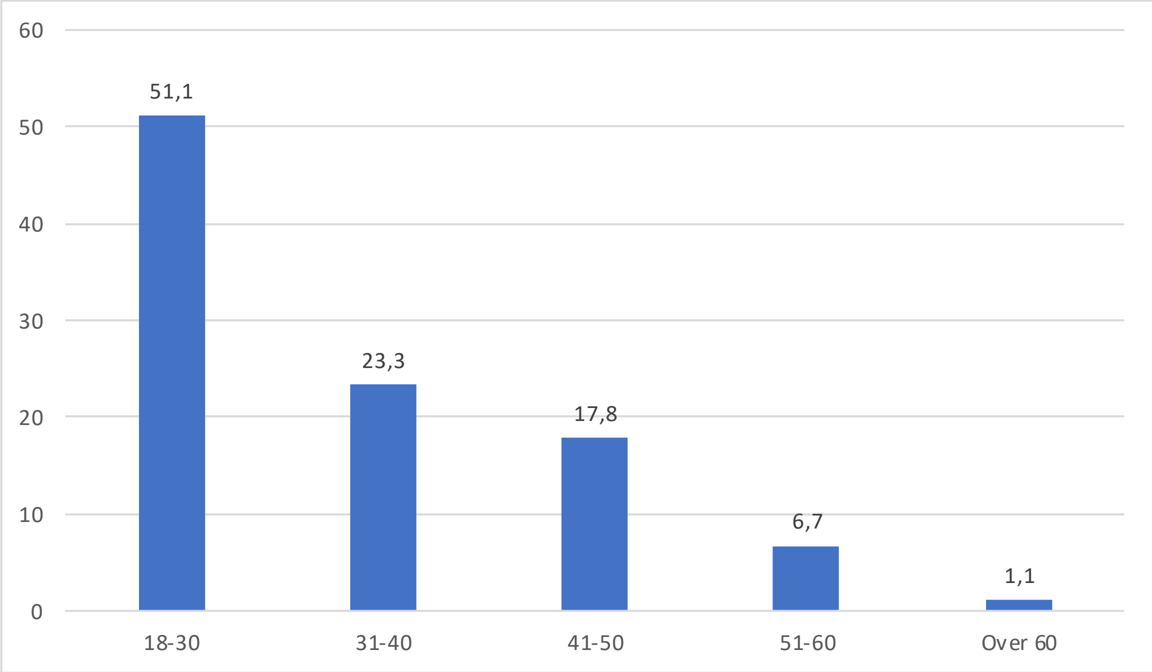



Figure 31 Age

3. Do you have vehicle?

Table 3 and Figure 3 present the respondents answers regarding the ownership of a vehicle. Specifically, the majority of the respondents state that they have a vehicle (90%).

Table 13: Own a vehicle

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Yes | 81 | 90.0 | 90.0 | 90.0 |
| No | 9 | 10.0 | 10.0 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

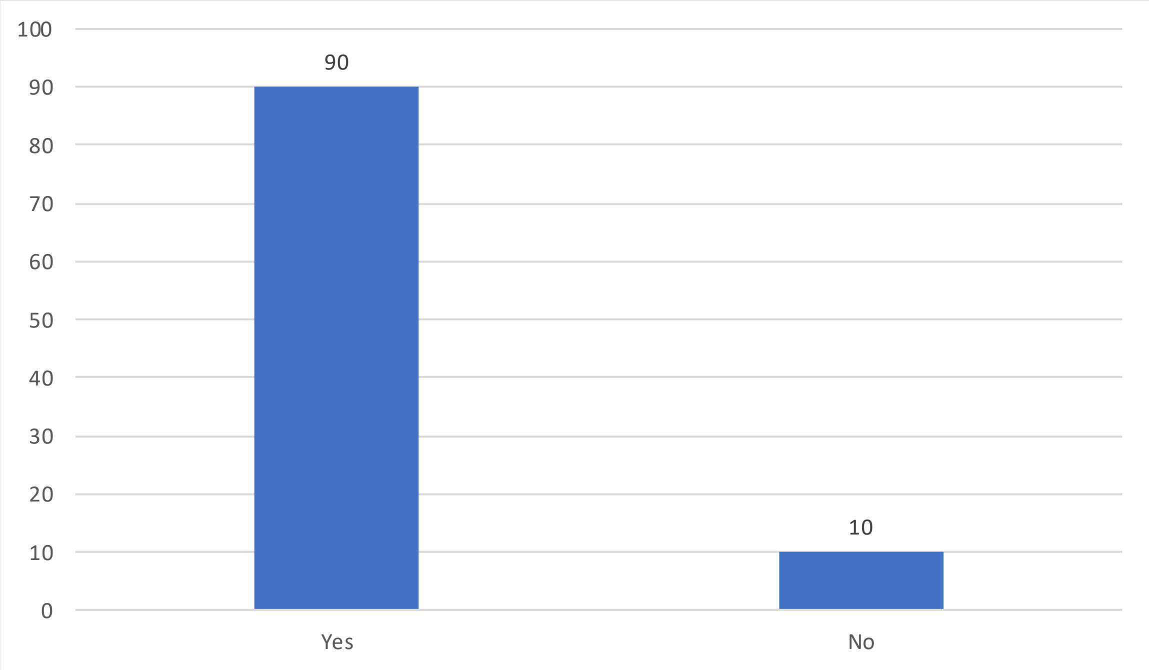



Figure 32 Own a vehicle

4. How many times a week are you required to drive in your town?

Table 4 and Figure 4 present the respondents' answers regarding the times per week that they required to drive into their town. Specifically, the majority of the respondents travel to their town 5 days per week (45.5%), while 14.8% one day and 12.5% two days.

Table 14: How many times a week are you required to drive in your town?

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| 1 day of week | 13 | 14.4 | 14.8 | 14.8 |
| 2 days of week | 11 | 12.2 | 12.5 | 27.3 |
| 3 days of week | 8 | 8.9 | 9.1 | 36.4 |
| 4 days of week | 8 | 8.9 | 9.1 | 45.5 |
| 5 days of week | 40 | 44.4 | 45.5 | 90.9 |
| 7 days of week | 1 | 1.1 | 1.1 | 92.0 |
| It varies depending if I am on placement | 7 | 7.8 | 8.0 | 100.0 |
| Total | 88 | 97.8 | 100.0 | |
| N/A | 2 | 2.2 | | |
| Total | 90 | 100.0 | | |

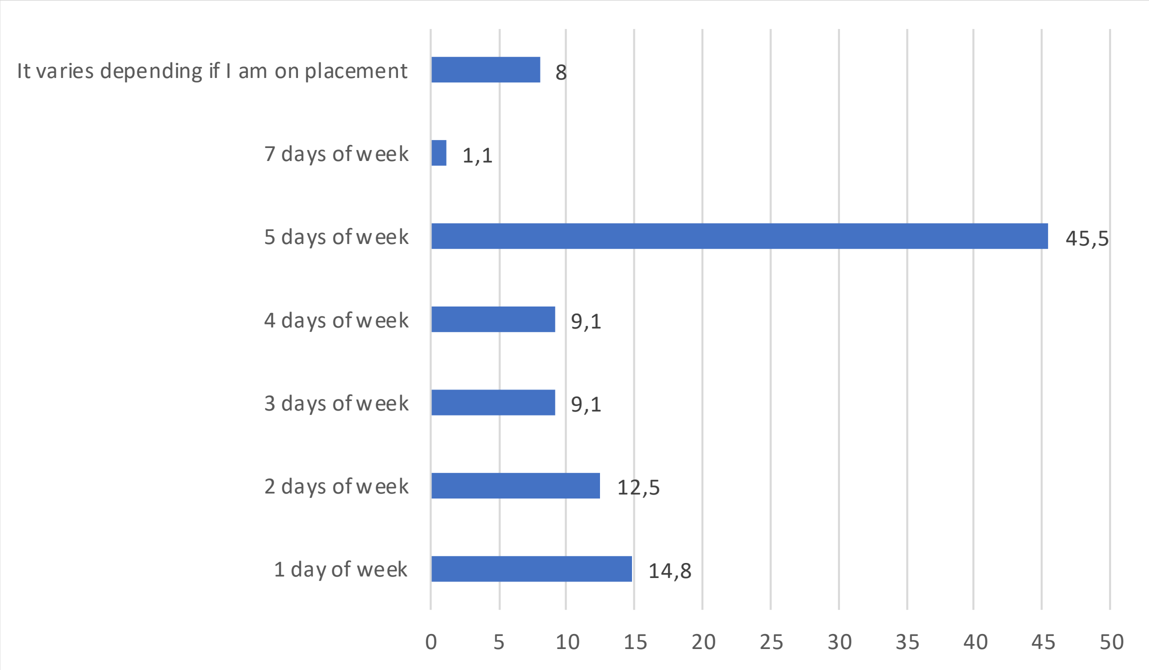



Figure 33

5. When you drive to your town, where do you currently park?

Table 5 and Figure 5 present the respondents' answers regarding where they currently park when they drive to their town. Specifically, the majority of the respondents park at the nearest pay and display meter (31%) while 28.7% prefer a council owned car park and 24.1% the two hours free parking spaces. On the contrary, only 12.6% do not drive in the town.

Table 15: When you drive to your town, where do you currently park

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| At the nearest pay and display meter | 27 | 30.0 | 31.0 | 31.0 |
| A council owned car park | 25 | 27.8 | 28.7 | 59.8 |
| The two hours free parking spaces | 21 | 23.3 | 24.1 | 83.9 |
| I don't drive into my town | 11 | 12.2 | 12.6 | 96.6 |
| At a free parking space | 2 | 2.2 | 2.3 | 98.9 |
| Anywhere I find a free spot | 1 | 1.1 | 1.1 | 100.0 |
| Total | 87 | 96.7 | 100.0 | |
| N/A | 3 | 3.3 | | |
| Total | 90 | 100.0 | | |

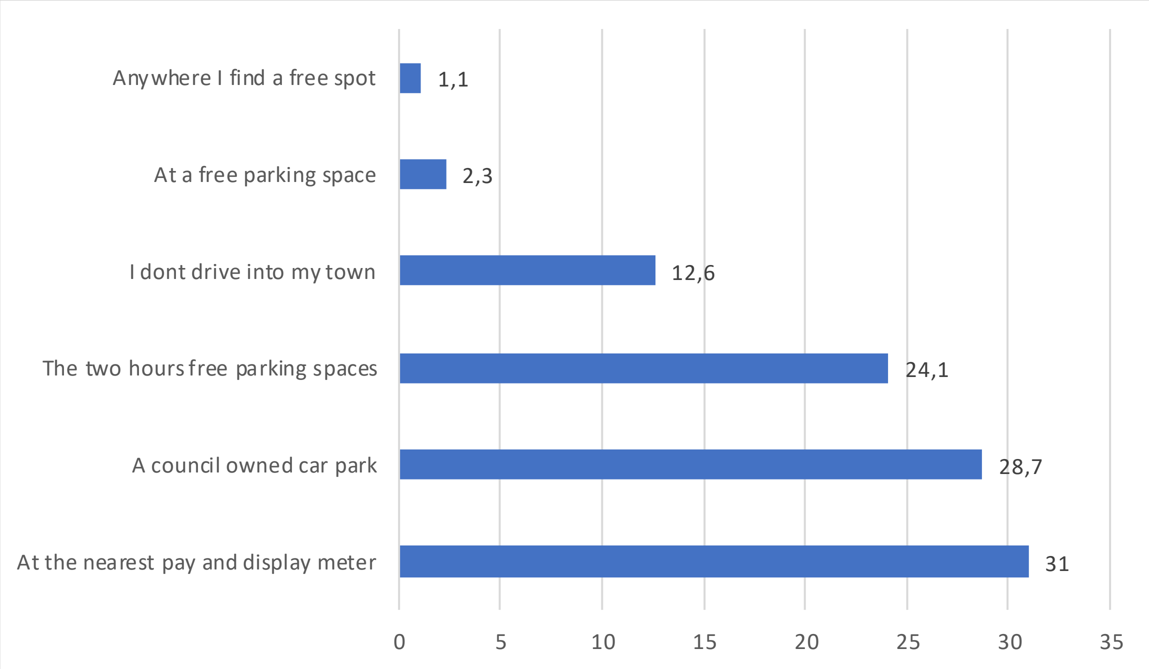



Figure 34 Where do you park in town?

6. How much do you pay daily for parking?

Table 6 and Figure 6 present the respondents' answers regarding the amount of money they pay for parking daily. Specifically, the majority of the respondents pay nothing for parking on a daily basis, while 28.8% pay from 3 to 5 euros. Finally, 11.1% pay more than 5 euros and only 5.6% have a monthly access and payment.

Table 16: How much do you pay daily for parking?

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| I pay nothing | 49 | 54.4 | 54.4 | 54.4 |
| 3.00-3.99 euros | 13 | 14.4 | 14.4 | 68.9 |
| 4.00-4.99 euros | 13 | 14.4 | 14.4 | 83.3 |
| 5+ euros | 10 | 11.1 | 11.1 | 94.4 |
| I pay monthly | 5 | 5.6 | 5.6 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

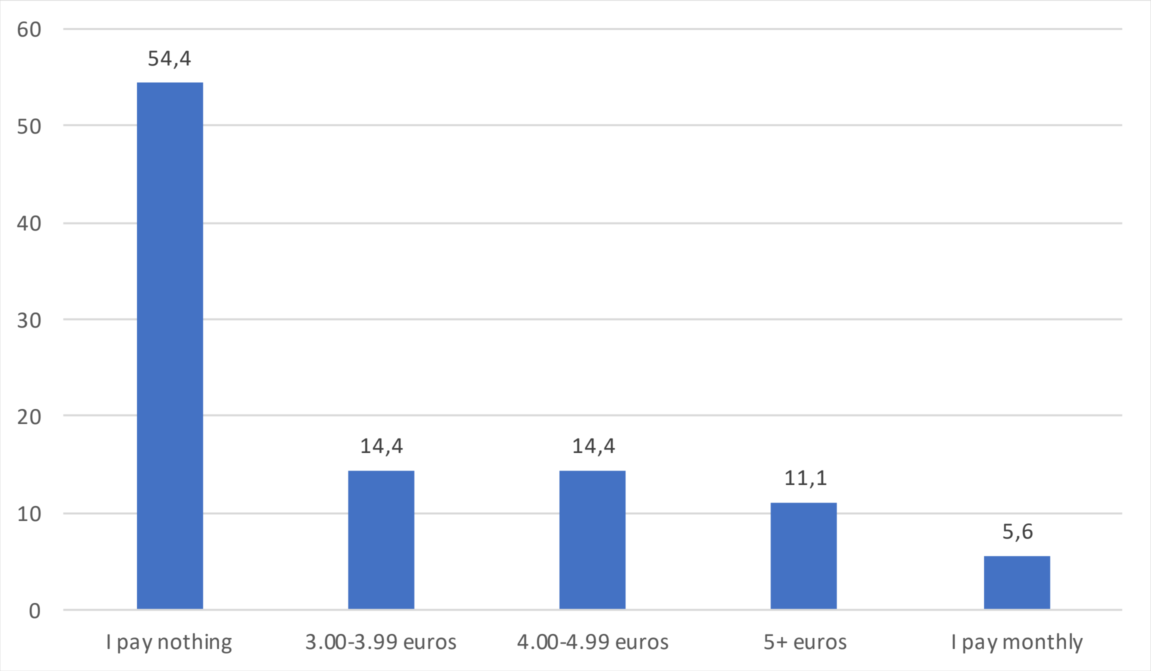



Figure 35 Cost

- Subjective Norm

Table 7 and Figure 7 present the respondents' answers regarding subjective norm. Specifically, the respondents state at greater extent that most people who are important to them would approve if they use smart parking (M = 2.91), following by stating that the media influences them to use smart parking (M = 2.81) and that their family expects them to use smart parking (M = 2.78). On the contrary, the respondents state less that most of their family members use smart parking regularly (M = 2.17) and that most of their friends use smart parking regularly (M = 2.31).

Table 17: Subjective norm statements

| | **Mean** |
|---|---|
| Most of my friends use smart parking regularly | 2.31 |
| Most of my family members use smart parking regularly | 2.17 |
| Most of my co-workers use smart parking regularly | 2.45 |
| Most people who are important to me think I should use smart parking | 2.72 |
| Most people who are important to me would approve if I use smart parking | 2.91 |
| My friends expect me to use smart parking | 2.76 |
| My family expects me to use smart parking | 2.78 |
| Media influences me to use smart parking | 2.81 |
| Famous people influence me to use smart parking | 2.54 |

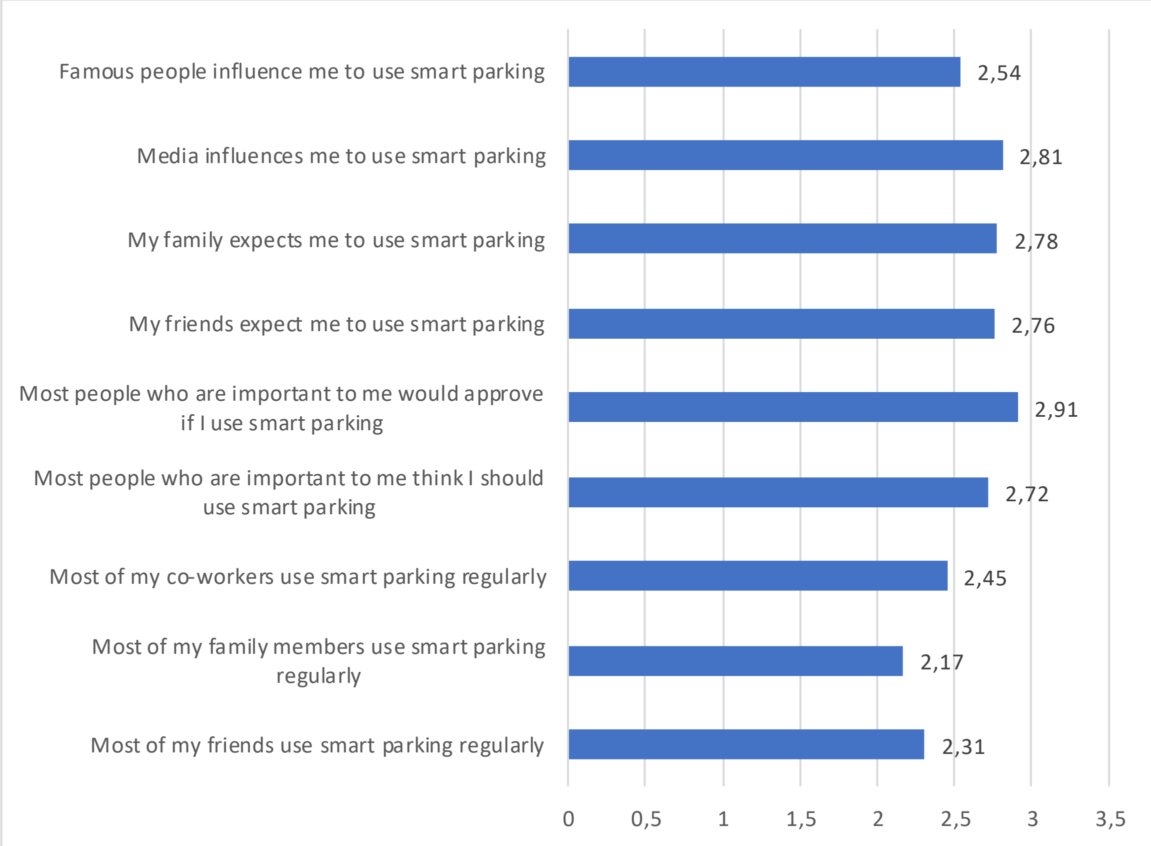



Figure 36 Subjective norm

- Value for money

Table 8 and Figure 8 present the respondents' answers regarding value for money statements. Specifically, the respondents state at greater extent that compared with other parking options, smart parking is good value for money (M = 3.10), following by stating that they received what they paid for (M = 2.96) and that they see value for the money they paid (M = 2.87). On the contrary, the respondents state less that the service is good for the price paid (M = 2.57).

Table 18: Value for money statements

| | **Mean** |
|---|---|
| The service is good for the price paid | 2.57 |
| The fare is very reasonable | 2.71 |
| I received what I paid for | 2.96 |
| I see value for the money I paid | 2.87 |
| Compared with other parking options, smart parking is good value for money | 3.10 |

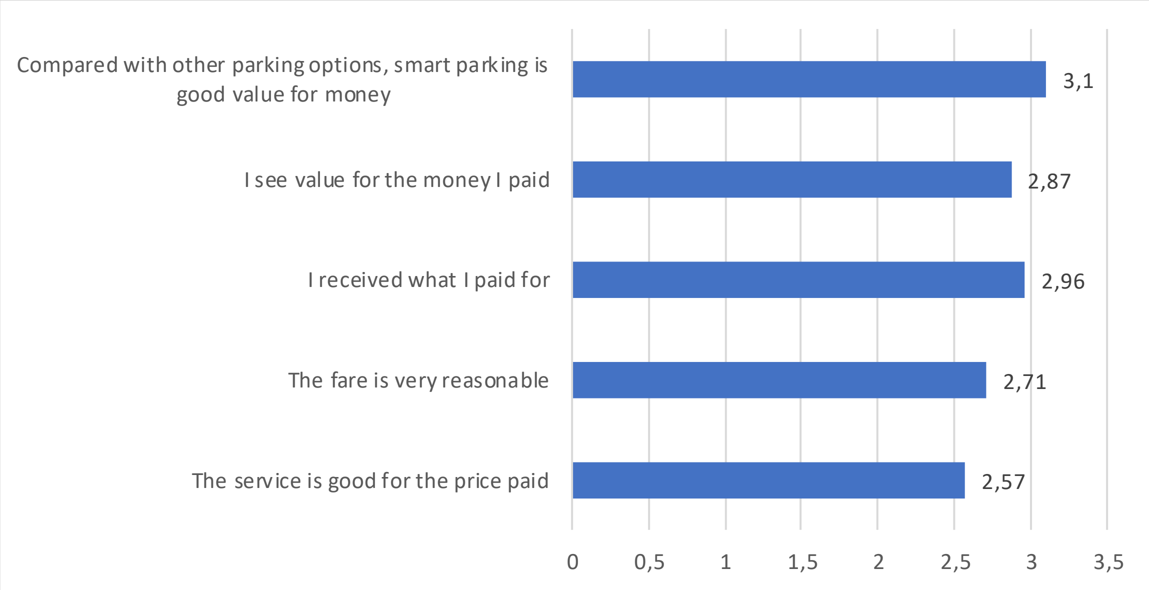


Figure 37 Value for money

- Loyalty

Table 9 and Figure 9 present the respondents' answers regarding loyalty statements. Specifically, the respondents state at greater extent that they would like to come back to this parking in the near future (M = 3.03), following by stating that they will come back to smart parking anytime they are looking for parking (M = 2.96) and that they will tell their friends about this smart parking (M = 2.96). On the contrary, the respondents state less that smart parking is their first choice anytime they are looking for parking (M = 2.66).

Table 19: Loyalty statements

| | **Mean** |
|---|---|
| I will come back to smart parking anytime I am looking for parking | 2.96 |
| Smart parking is my first choice anytime I am looking for parking | 2.66 |
| I will encourage friends and relatives to use smart parking | 2.91 |
| I would like to come back to this parking in the near future | 3.03 |
| I will tell my friends about this smart parking | 2.96 |
| I will recommend this smart parking to others | 2.93 |

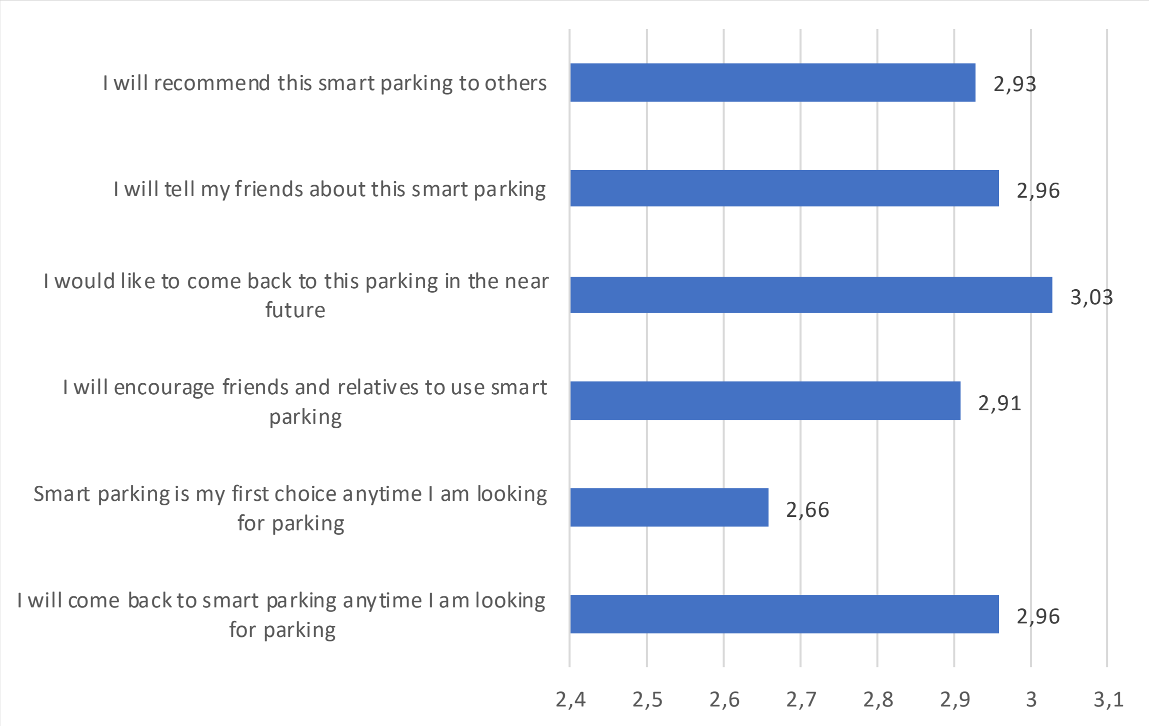



Figure 38 Loyalty

- Overall scores

Table 10 and Figure 10 present the mean score for the variables. Specifically, loyalty presents the higher mean score (M = 2.91, SD. = 1.03) and it can be characterized as average. Moreover, value for money can be characterized as close to average with a mean score of 2.84 (SD = .894), while subjective norm is at low levels (M = 2.60, SD = .952).

Table 20: Overall scores

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Subjective norm | 90 | 1.00 | 5.00 | 2.6099 | .95236 |
| Value for money | 90 | 1.00 | 5.00 | 2.8467 | .89445 |
| Loyalty | 90 | 1.00 | 5.00 | 2.9130 | 1.03504 |

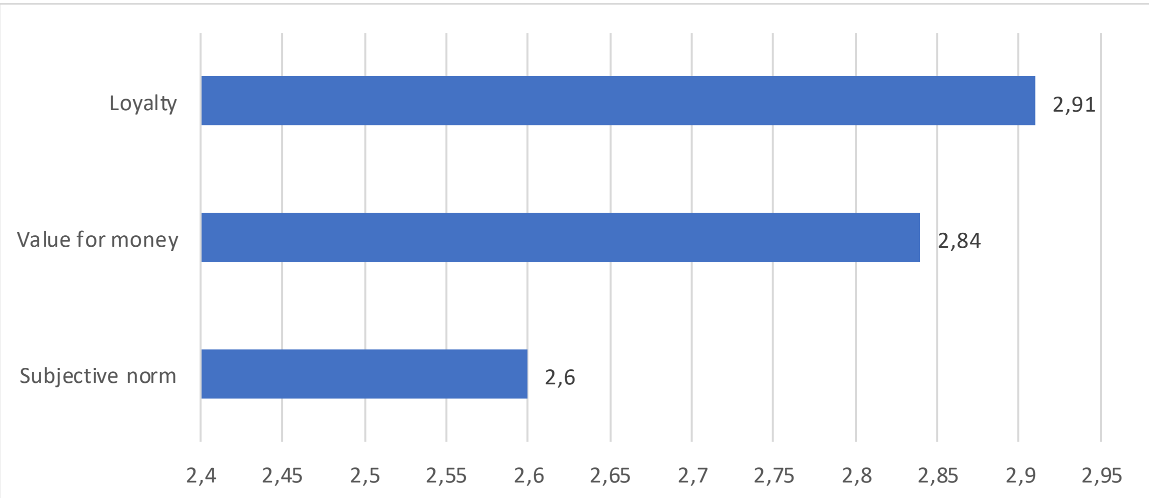



Figure 39 Overall statements

10. I use online parking website or parking app to find parking locations

Table 11 and Figure 11 present the respondents' answers regarding whether they use online parking website or parking app to find parking locations. Specifically, the majority of the respondents state that they have never used an online parking website or a parking app to find parking locations (48.9%) and 21.1% they usually do.

Table 21: I use online parking website or parking app to find parking locations

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Yes, I usually do | 19 | 21.1 | 21.1 | 21.1 |
| Yes, I often do | 17 | 18.9 | 18.9 | 40.0 |
| No, I have never used online | 44 | 48.9 | 48.9 | 88.9 |
| Yes, I always do | 10 | 11.1 | 11.1 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

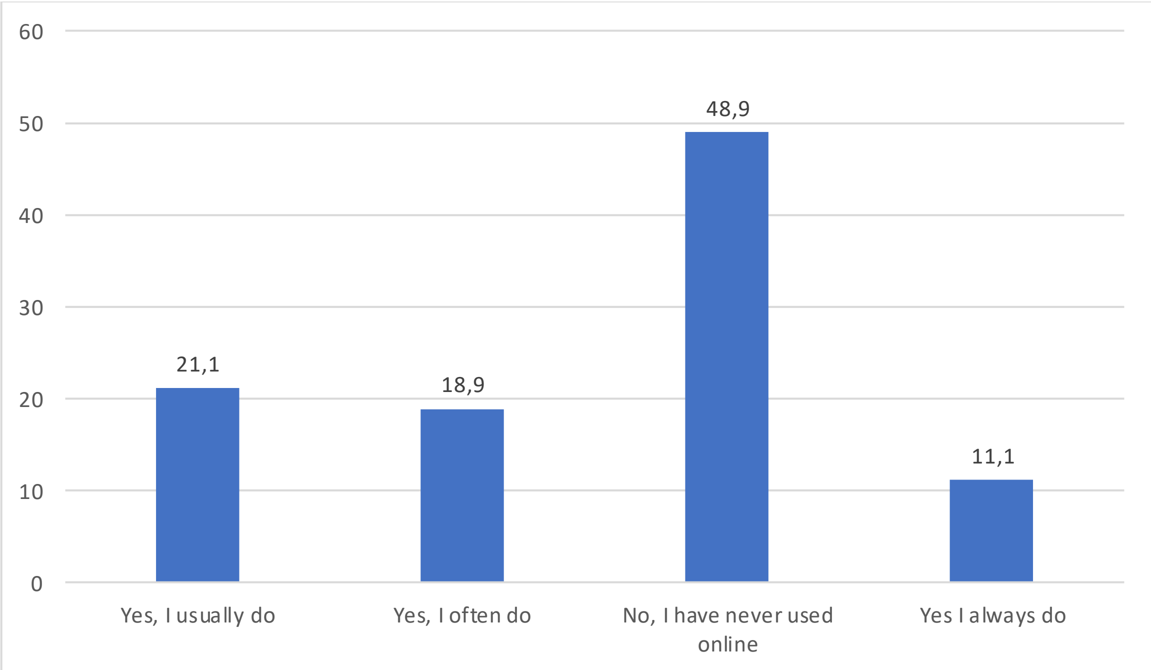


Figure 40 Use of parking applications

11. In general, I search for a parking to get directions ahead of my actual trip

Table 12 and Figure 12 present the respondents' answers regarding whether in general, they search for a parking to get directions ahead of their actual trip. Specifically, 30% of the respondents state that they agree that they search for a parking to get directions ahead of their actual trip, while 21.1% do not do it.

Table 22: In general, I search for a parking to get directions ahead of my actual trip

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Strongly disagree | 10 | 11.1 | 11.1 | 11.1 |
| Disagree | 19 | 21.1 | 21.1 | 32.2 |
| Neutral | 27 | 30.0 | 30.0 | 62.2 |
| Agree | 27 | 30.0 | 30.0 | 92.2 |
| Strongly agree | 7 | 7.8 | 7.8 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

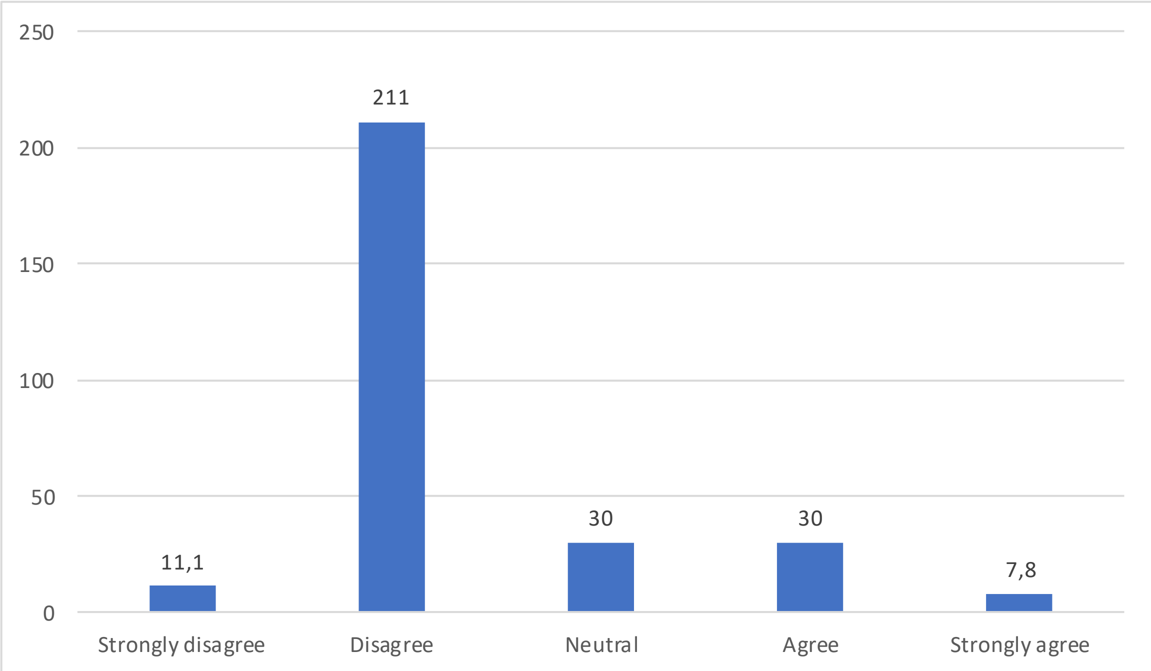



Figure 41 Parking applications

12. If you are using online parking website(s) or app(s), please specify the reason(s)

Table 13 and Figure 13 present the respondents' answers regarding why they are using an online parking website or app. Specifically, 31.1% of the respondents state that they use an online parking website or app in order to find the shortest path to their final destination, following by 25.6% who use them to find various locations and 22.2% for comparing different prices.

Table 23: If you are using online parking website(s) or app(s), please specify the reason(s)

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| To find various locations | 23 | 25.6 | 25.6 | 25.6 |
| To find the shortest path to my final destination | 28 | 31.1 | 31.1 | 56.7 |
| To get directions | 19 | 21.1 | 21.1 | 77.8 |
| To compare different prices | 20 | 22.2 | 22.2 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |


Figure 42

13. If you are not using a parking website(s) or app(s), please specify the reason(s)

Table 14 and Figure 14 present the respondents' answers regarding why they are using an online parking website or app. Specifically, 41.1% of the respondents state that they do not know a specific website or an app to find a parking, following by 40% who state that they like to find a parking when they reach their destination.

Table 24: If you are not using a parking website(s) or app(s), please specify the reason(s)

| | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| I like to find a parking when I reach my destination | 36 | 40.0 | 40.0 | 40.0 |
| Parking websites or apps are not useful | 17 | 18.9 | 18.9 | 58.9 |
| I don't know specific website or an app to find a parking | 37 | 41.1 | 41.1 | 100.0 |
| Total | 90 | 100.0 | 100.0 | |

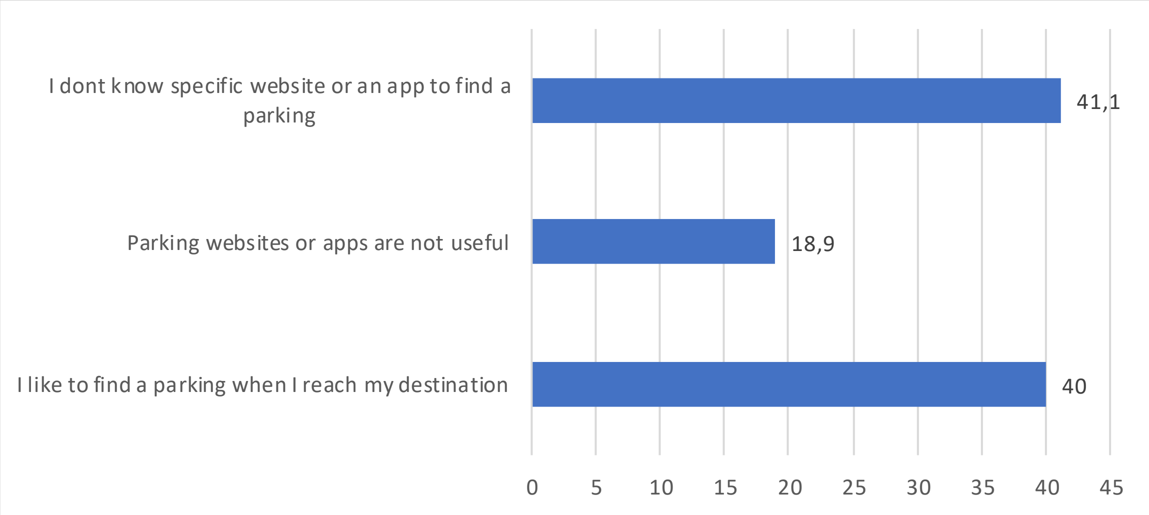



Figure 43

## 5.2. Inferential Statistics

**Correlation between the variables**

Pearson correlation was used in order to test the relationship between the variables (Table 15). The findings suggest that subjective norm presents a positive relationship with value for money ($r = .481$, $p < 0.05$) and loyalty ($r = .673$, $p < 0.05$). As a result, the higher the levels of subjective norm, the higher are also those of value for money and loyalty. Additionally, value for money also presents a positive strong relationship with loyalty ($r = .690$, $p < 0.05$). Specifically, the higher the value for money, the higher the loyalty of the respondents to the parking company.

Table 25: Correlations

| | | Subjective norm | Value for money | Loyalty |
|---|---|---|---|---|
| Subjective norm | Pearson Correlation | 1 | .481** | .673** |
| | Sig. (2-tailed) | | .000 | .000 |
| | N | 90 | 90 | 90 |
| Value for money | Pearson Correlation | .481** | 1 | .690** |
| | Sig. (2-tailed) | .000 | | .000 |
| | N | 90 | 90 | 90 |
| Loyalty | Pearson Correlation | .673** | .690** | 1 |
| | Sig. (2-tailed) | .000 | .000 | |
| | N | 90 | 90 | 90 |

**. Correlation is significant at the 0.01 level (2-tailed).

**Demographics and variable scores**

Independent samples t-test and One-way ANOVA were used in order to test whether there are significant differences on the three variables between demographic characteristics and personal choices (Table 16). The findings suggest that all three variables present significant differences ($p < 0.05$) regarding the parking choice. Specifically, subjective norm presents higher levels for those who select a council owned car park (2.95), and then for those who prefer the two hours free parking spaces (2.73), and those who select to park at the nearest pay and display meter (2.64). Regarding value for money, a council owned car park show higher levels of value for money (3.27), following by the two hours free parking spaces (2.89), and the parking at the nearest pay and display meter (2.72). Finally, loyalty levels are higher for those who select a council owned car park (3.32), following by those who select to park at the nearest pay and display meter (3.06), and those that park at the two hours free parking spaces (2.97).

Table 26: Demographics and variable scores

| | **Variables (p-value)** | | |
|---|---|---|---|
| | **Subjective Norm** | **Value for money** | **Loyalty** |
| Gender | .149 | .928 | .432 |
| Age | .059 | .768 | .954 |
| Ownership | .057 | .994 | .067 |
| Time in town | .637 | .911 | .725 |
| Parking | **.020** | **.008** | **.004** |
| Cost | .162 | .230 | .266 |

**Chapter 6 Results of the research**

The research sample consists of females by 52.3% while the majority of the respondents were from 18 to 30 years old (51.1%), 90% of the respondents state that they have a vehicle, 45.5% that they travel to their town 5 days per week, 31% parks at the nearest pay and display meter while 28.7% prefer a council owned car park and 24.1% the two hours free parking spaces.

*Research Question 1: Which are the respondents' perceptions regarding the smart parking app?*

The respondents react on the scales measured with loyalty to be at average levels, value for money to be close to average and subjective norm to present low levels. Moreover, the majority of the respondents state that they have never used an online parking website or a parking app to find parking locations (48.9%), 30% of the respondents state that they agree that they search for a parking to get directions ahead of their actual trip, while 21.1% do not do it, 31.1% of the respondents state that they use an online parking website or app in order to find the shortest path to their final destination, following by 25.6% who use them to find various locations and 22.2% for comparing different prices. Finally, 41.1% of the respondents state that they do not know a specific website or an app to find a parking, following by 40% who state that they like to find a parking when they reach their destination.

*Research question 2: Is there a statistically significant relationship between subjective norm, value for money and loyalty?*

The findings suggest that subjective norm presents a positive relationship with value for money and loyalty. As a result, the higher the levels of subjective norm, the higher are also those of value for money and loyalty. Additionally, value for money also presents a positive strong relationship with loyalty. Specifically, the higher the value for money, the higher the loyalty of the respondents to the parking company.

*Research question 3: Are there any statistically significant differences on variable levels (subjective norm, value for money and loyalty) based on the demographics (Gender, age, ownership, time in town, parking, cost) of the respondents?*

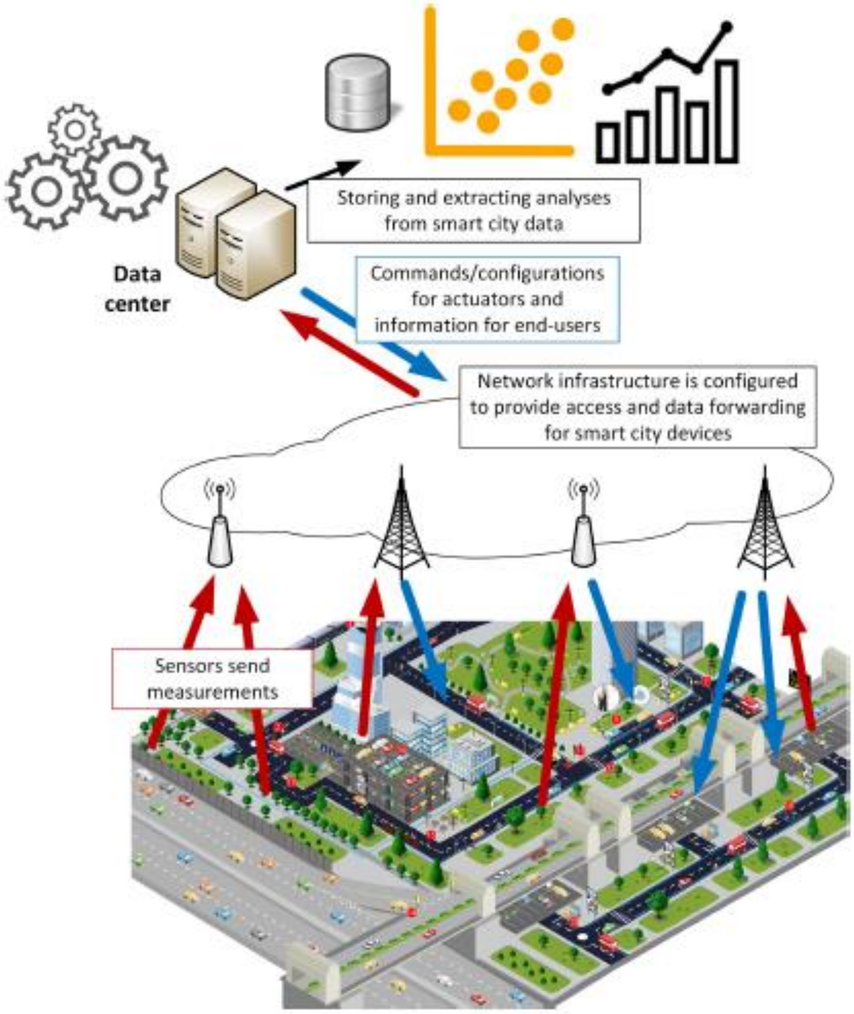
The findings suggest that all three variables (subjective norm, value for money and loyalty) present significant differences regarding the parking choice. Specifically, subjective norm presents higher levels for those who select a council owned car park, and then for those who prefer the two hours free parking spaces, and those who select to park at the nearest pay and display meter. Regarding value for money, a council owned car park shows higher levels of value for money, following by the two hours free parking spaces, and the parking at the nearest pay and display meter. Finally, loyalty levels are higher for those who select a council owned car park, following by those who select to park at the nearest pay and display meter, and those that park at the two hours free parking spaces.

## CHAPTER 7. CONSLUSIONS-SUGGESTIONS

### 7.1 Conclusions

IoT vision is extended through the paradigm of smart city. The goal of this scenario applied in an urban environment is to exploit the data collected by multiple sensors and to use the various wireless communication networks, in order to provide optimal services to citizens, to improve city management, to react to city's events very fast and in general to enhance citizens' quality of life. Within this framework, ICT infrastructure is more than necessary, as it is depicted in the following figure.

Figure 44. A representation of a smart city environment which highlights the role of ICT infrastructure in providing connectivity to smart city devices




Source: Chiariotti et al., 2017, p. 2

In general, there are numerous advantages stemming from the use of IoT in Smart Cities, which are depicted in the following table.

Table 27. Advantages of using IoT in Smart Cities

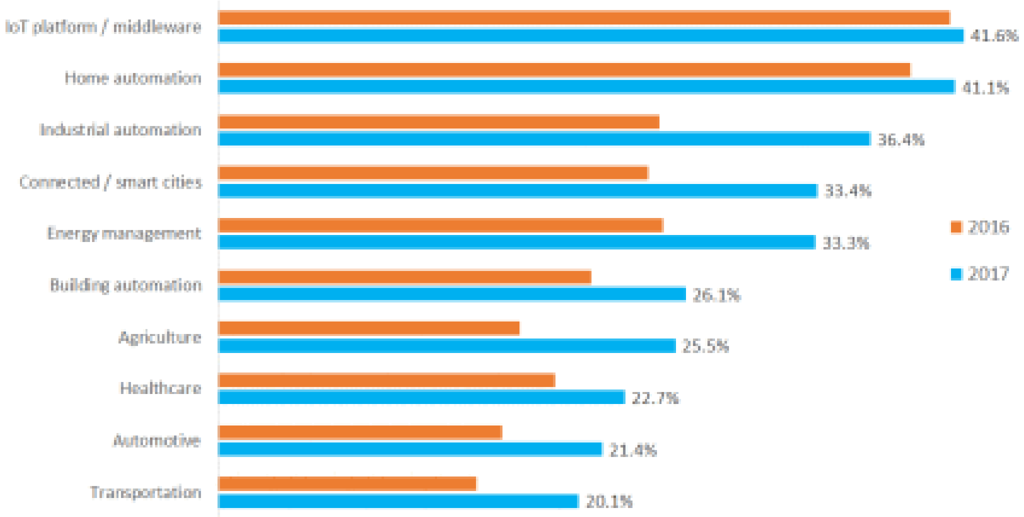
| |
|---|
| Lessening asset utilization, quite vitality and water, consequently adding to decreases in $CO_2$ discharges |
| Enhancing the use of existing foundation limit, subsequently enhancing personal satisfaction and diminishing the requirement for customary development ventures |
| Making new administrations accessible to residents and suburbanites, for example, constant direction on how best to misuse various transportation modalities |
| Enhancing business ventures through the distribution of continuous information on the operation of city administrations |
| Uncovering how requests for vitality, water and transportation top at a city scale so that city chiefs can work together to smooth these pinnacles and to enhance flexibility |

Source: Ben Sta, 2017, p. 411

Smart cities may be inevitable, but there are still major issues to be addressed, as they were indicated in the previous analysis. However, IoT in smart cities is a promising field, given the fact that smart cities are friendlier to the citizens and the environment, while they also incorporate applications that are cost-efficient. Based on the future of today cities as smart cities, the interaction and communication between the various stakeholders is of great importance. This was indicated through the description of the various projects running within the concept of smart city.

According to the IoT Developer Survey 2017, even more participants in 2017 were involved in IoT projects. Even though industries such as IoT Platform and Home Automation industries dominated in the field of IoT, others operating in Industrial Automation, Smart Cities, Energy Management reported significant growth between 2016 to 2017, as it is illustrated in the figure below.

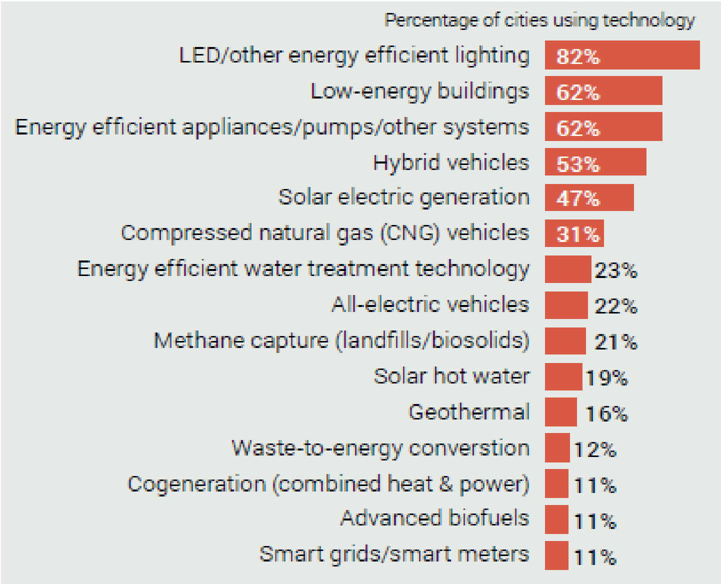
Figure 45. Industries operating in IoT, 2016-2017




Source: IoT Developer Trends 2017 Edition, 2017

The technologies that have been used so far to a great extent, according to a survey conducted by The U.S. Conference of Mayors in 204 cities, are the replacement of traditional street lights with LEDs, low-energy buildings, and energy efficient appliances/pumps/other systems. On the contrary, cogeneration (combined heat & power), Advanced biofuels and Smart grids/smart meters are the technologies less used, as it can be seen from the figure below.

Figure 46. Technologies already deployed by cities




Source: Smart Cities Council, 2015, p. 2

Overall, the previous analysis indicated that through the Internet of Things (IoT), it is possible to increase the number of embedded devices of all kinds (eg sensors, mobile phones, cameras, smart meters, smart cars, lanterns, smart home appliances, etc.), communication and data exchange over the Internet. Although the idea of using embedded systems to control tools and devices has been proposed for decades now, with every new generation, ever-increasing computing and communication capabilities create new opportunities and new challenges. As IoT becomes an active research area, different methods are explored from different angles to promote the development and popularity of IoT. One trend is to view IoT as Web of Things (WoT) where open Web standards for information exchange and device interoperability are supported. With the intrusion of smart things into the existing Web, conventional web services are enriched with the physical services of the world. This vision of WoT allows a new way to limit the barrier between virtual and natural worlds (Zeng et al., 2011).

According to Saidu et al. (2015), IoT is still young, as some of his concepts and technologies that would allow him to be fully implemented have not yet become familiar. It will take a step-by-step process before the concepts of autonomous device integration into device communication (Internet background) become part of the daily life of Internet users, but until then IoT will first be accepted into mini-networks, home appliances, etc; In the long run, when it finally becomes accepted and fully implemented, there will be a chance of an explosion in some markets, with some key players involved in specific industries such as telecommunications, data mining, advertising, software creation.

The fact that smart technologies are not yet fully adopted by citizens can also be seen from the results of the present small-scale study. More precisely, it was found that a Smart Parking application is not so easy to be used, it is not so enjoyable, it cannot so much lead to decreased queue up time and find car park quickly, and it cannot enhance the performance of the users. Perhaps the fact that the application is not so easy to be used is the reason for which the users cannot find park quickly and in less time, resulting in increased overall performance in their life. Hence, there are not characterized by high levels of overall satisfaction from using such systems, by the intention to continue to use them and the intention to recommend them to other people. It is assumed that due to the age of the participants in the research and the fact that they use social media, their knowledge and skills in using applications is not the reason behind these results. On the contrary, the respondents claimed that the actual usefulness of the application, the functionality of the application and the concerns about the protection of their personal data are the main reasons for which they would choose to stop using a Smart Parking application.

This leads to the discussion concerning the challenges that exist within the framework of adopting such technological tools. In fact, three main challenges that should be overcome within the framework of digitalization according to the Copenhagen Cleantech Cluster (2012) are: a) Enabling the technology to gather data; b) Enabling the technology to communicate; c) Making the technology multi-functional.

Box 5. Challenges to overcome towards digitalization

1. Enabling the technology to gather data First of all, being a type of Smart City technology means being able to constantly gather information about the city which can be used by the technology itself in order to adapt to the most sustainable and smart behaviour. An example of this is a Smart Building System, which constantly gathers data about the performance of a building, which it then uses to optimize energy use.
2. Enabling the technology to communicate Secondly, a type of technology is not smart just because it is able to gather data. It should also be able to share that data with people or other technologies or borrow relevant data from elsewhere. In this sense, smart technology should be able to communicate with the rest of a Smart City system. For this to be the case, it needs to be able 'speak the same language' as the other devices in the Smart City system. Furthermore, it needs to be connected to a common communicative platform where information can be shared and interoperability can be promoted (e.g. a smart grid).
3. Making the technology multi-functional Thirdly, although technology which is able to gather data and communicate with other technologies is indeed smart, truly smart technologies are multi-functional. This means that they provide solutions to multiple problems. One example could be the electric vehicle. This not only leads to less congestion; in connection with a smart grid it can also serve as an energy buffer, which would help level out the energy supply and demand curve.

Source: Copenhagen Cleantech Cluster, 2012, p. 8

In order for a city to become a smart city on the basis of the IoT / WoT, several challenges should be solved. These issues primarily concern data integrity, communication, privacy and security. Due to the large number of devices that will participate in an IoT scenario, it is likely that as the data is routed from one place to another, the privacy of the users and the integrity of the data is affected. This will most likely affect the outcome and conclusions generated by the smart city, resulting in negative decision-making and compromising the integrity of the system, resulting in a loss of income and user satisfaction. Also, if network providers are going to take advantage of the benefits of the Internet then there must be a consistent and reliable way of communicating between Internet devices. Already, there is a shift from IPV4 to IPV6 to solve the problem of device addressing in IoT, while various IoT / WoT solutions have been proposed but these solutions have not effectively addressed all the problems. Therefore, further research is needed to look into the proposed proposed architectures and proposed solutions for integrating IoT into the smart city, along with the strengths and opportunities of the city.

### 7.2 Limitations and suggestions for further research

The present study examined the concept of smart city based on Internet of Things (IoT) in the following domains: traffic-transportation, energy, and mobility. The smart city concept, though, is wider, including among others aspects of health, home, environment, policing and governance in the public sector. Hence, a future study could provide a much more holistic approach to smart city, discussing other domains as well.

Apart from the focus of this research, one more limitation refers to the methodology used and the technology examined in the study. More precisely, this study was primarily a literature review and for this reason secondary data were used as the method for conducting this research concerning various aspects of smart cities. However, this limits the range of the results, since they are based exclusively upon existing reports and paradigms. In addition, there was a small-scale study to citizens concerning only applications related to smart parking. Thus, a future study could also employ a primary research to both citizens and authorities, and in more domains of smart cities. Such a study, namely a large-scale study, including citizens could provide results concerning the adoption of ICT and IoT within the concept of smart city, advantages of smart city applications – namely how these applications have improved their quality of life – and disadvantages. In addition, a research to citizens could yield outcomes concerning future needs and demands that could perhaps be met through IoT, WoT and ICT. On the other hand, a research to authorities could provide results with regard to potential obstacles in implementing smart city applications, future perspectives, and factors that are necessary in order to implement a smart city. Additionally, such a study could provide conclusions regarding the reasons for which some cities do not invest in smart applications based on IoT.

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# APPENDIX. QUESTIONNAIRE

SMART PARKING SYSTEMS

1. Gender *

- Female
- Male
- Prefer not to say
- Other ____________________

2. Age *

- 18-30
- 31-40
- 41-50
- 51-60
- Above 60

3. Do you have vehicle? *

- Yes
- No

4. How many times a week are you required to drive in your town? *

- 1 day of week
- 2 days of week
- 3 days of week
- 4 days of week
- 5 days of week
- It varies depending if I am on placement
- Other: ____________________

5. When you drive to your town, where do you currently park? *

- I don't drive into my town
- At the nearest pay and display meter
- A council owned car park
- The two hours free parking spaces
- Other ____________________

6. How much do you pay daily for parking? *

- I pay nothing
- 3,00 - 3,99 euro
- 4,00 - 4,99 euro
- 5 + euro
- I pay monthly

7. Subjective Norm *

| | Strongly disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| **Most of my friends use smart parking regularly** | | | | | |
| **Most of my family members use smart parking regularly** | | | | | |
| **Most of my co-workers use smart parking regularly** | | | | | |
| **Most people who are important to me think I should use smart parking** | | | | | |
| **Most people who are important to me would approve if I use smart parking** | | | | | |
| **My friends expect me to use smart parking** | | | | | |
| **My family expects me to use smart parking** | | | | | |
| **Media influences me to use smart parking** | | | | | |
| **Famous people influence me to use smart parking** | | | | | |

8. Value for money *

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| **The service is good for the price paid** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **The fare is very reasonable** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I received what i paid for** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I see value for the money i paid** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **Compared with other parking options, smart parking is good value for money** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

9. Loyalty *

| | Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|---|
| **I will come back to smart parking anytime I am looking for parking** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **Smart parking is my first choice anytime I am looking for parking** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I will encourage friends and relatives to use smart parking** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I would like to come back to this parking in the near future** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I will tell my friends about this smart parking** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |
| **I will recommend this smart parking to others** | ⬭ | ⬭ | ⬭ | ⬭ | ⬭ |

10. I use online parking website or parking app to find parking locations *

- Yes, I always do
- Yes, I usually do
- Yes, I often do
- No, I have never used online

11. In general, I search for a parking to get directions ahead of my actual trip *

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

12. If you are using online parking website(s) or app(s), please specify the reason(s): *

- To find various locations
- To get directions
- To compare different prices
- To find the shortest path to my final destination

13. If you are not using a parking website(s) or app(s), please specify the reason(s): *

- [ ] I don't know specific website or an app to find a parking
- [ ] Parking websites or apps are not useful
- [ ] I like to find a parking when I reach my destination
- [ ] Other: ____________________