Universidade de Aveiro
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Departamento de Economia, Gestão, Engenharia Industrial e Turismo

Diogo Miguel Mendes Correia

Ferramenta otimizada para a avaliação do Índice de Inteligência de uma Cidade

Optimised tool for the evaluation of the Smart City Index

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia e Gestão Industrial realizada sob a orientação científica da Doutora Leonor da Conceição Teixeira, Professora Auxiliar do Departamento de Economia, Gestão, Engenharia Industrial e Turismo da Universidade de Aveiro.

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palavras-chave

Cidade Inteligente, IoT (“Internet das Coisas”), Interoperabilidade, KPIs (Indicadores Chave de Desempenho), Sustentabilidade e Índice de Cidade Inteligente.

resumo

As cidades estão a ficar superlotadas, portanto os seus decisores precisam de adotar medidas que melhorem os processos e condições de vida dos seus cidadãos. O objetivo do presente trabalho é encontrar uma ferramenta que permita às cidades em todo o mundo medir o nível de inteligência das mesmas, identificando desta forma áreas de atuação em termos de planeamento urbano e políticas a fomentar.
Ao contrário de outros rankings/índices, esta ferramenta terá em consideração a opinião do cidadão, uma vez que uma Cidade Inteligente é aquela que promove o melhor nível de qualidade de vida aos seus cidadãos. Através de um inquérito conduzido por questionário, alguns cidadãos foram convidados a avaliar e priorizar um conjunto de diferentes KPIs e respetivas subdimensões, tendo estes sido encontrados com base em diferentes fontes de informação (literatura, estado da arte de factos reais observados e trabalho de benchmarking). Os resultados contribuíram para o cálculo de coeficientes que, por sua vez, representaram inputs para a formulação da expressão que poderá definir o índice de uma Cidade Inteligente.

keywords

Smart City, IoT (Internet of Things), Interoperability, KPIs (Key Performance Indicators), Sustainability and Smart City Index.

abstract

Cities are becoming overcrowded, therefore city administrations have to adopt measures to improve city processes and living conditions. The purpose of the present work is to find a tool which cities throughout the globe can use to measure its Smart City level and identifying areas of action in terms of urban planning and the politics they shall promote.
Unlike other indexes, this tool have into consideration citizen's opinion, because a Smart City shall be the city which promotes the better quality of life for its citizens. Through an inquiry, citizens are asked to evaluate and prioritize the different KPIs and Sub Dimensions, having these data been based on different sources of information (literature, state of the art of observed real facts and benchmarking work). The results have contributed to the calculation of the different coefficients and after that as inputs for the formulation of the equation that will define the Smart City index of a city.

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Abbreviations and acronyms

AI - Artificial Intelligence;

ETSI - European Telecommunications Standards Institute;

EV - Electric Vehicle;

GDP - Gross Domestic Product;

ICT - Information and Communication Technologies;

IEC - The International Electrotechnical Commission;

IoT - Internet of Things;

ISO - International Organization for Standardization;

NIST - National Institute of Standards and Technology;

SME – Small and Medium Enterprise;

UN – United Nations;

UNEP - United Nations Environment Programme;

US - United States;

WHO – World Health Organisation.

1. Introduction

Is there a single and unique way to adopt a Smart City strategy? What are the challenges and barriers cities have to face? What defines a Smart City? What are the Key Performance Indicators capable of evaluating the status of each city? What is the line that differentiates cities from Smart Cities? Those are very difficult and discussable questions which this work tries to discover what is behind each one of them and assist the reader with the respective answers and conclusions. A city must understand its ecosystem perfectly to define a strategy to improve its processes and aggregation of the information.

The main barriers for any city to foster “becoming a Smart City“ come not just from the lack of will and openness of their city officers or the absence of public infrastructures but also from the unavailability of the information that is given to them regarding this subject. It is important to state that the high-level decision makers shall not discard the intention of starting the improvement of their cities for the reason of belonging to a city too small, not having enough budget or just for the fact of not knowing how to start.

What is “Smart” for one city could not be “Smart” for another.

If we think in the different realities over the World, there are systems which their implementation could make sense to the society and at the same time be just a waste of public money for others. In a specific case, if for the US cities it is a priority to have public Wi-Fi installed, probably for European citizens it is more important to provide a unique multimodal ticket combining the different options of public transportation throughout the city, what can be explained for the lack of public transportation infrastructure (in the most part) of US cities due to the reduced price of gas leading citizens to use their private vehicle.

It is right to say that nowadays mobile network and broadband Internets are no more 3rd and 4th generation needs. No one wants to live in a place where you cannot connect to the rest of the world. Although it is important for cities to build basic infrastructure to fulfil those needs, the driver of a Smart City must be citizens and citizen engagement instead of the technology focus (IoT, AI, etc...). Only this way Cities would tackle the right issues.

To be able to better evaluate the development of each city it is necessary to have a common and normalized criterion to compare each other. This way, Key Performance Indicators and their Dimensions and Sub Dimensions must be outlined to compare and evaluate what is the current status of each city and find what should be their priorities based on citizens point of view.

1.1 Motivation and Context

For the past 2 years, because of the job of the author as Business Developer and Innovation Manager at Ubiwhere, a Research and Innovation SME, based in Aveiro, Portugal, founded in 2007, the gathering of information about this theme has been constantly rising. Ubiwhere is a company dedicated to research and development of innovative and user-centered software solutions for Smart Cities and the Future Internet sectors. Ubiwhere has a history of spinning off new companies and products, taking advantage of its core capabilities. One of the most successful stories is BikeEmotion, a company devoted to the development of the next generation of Electric Bike-Sharing. More recently, Ubiwhere in partnership with two more companies, Micro I/O and Wavecom, invested in founding and promoting a Smart City trademark called Citibrain, focused on unified systems for Smart Cities.

The author has been travelling around the world talking with and observing the several strategies the city decision makers in the different parts of the globe are thinking and prioritizing. Because of his contact with different realities, like in a smaller city called Ljubljana (the capital of Slovenia) where you can pick a normal bike for only one euro per month and they call it a Smart Bike Sharing system or in Birmingham, Alabama where they have for a few years implemented the renting of electric bikes to assist the users in the act of pedal and where you can drop the bike wherever you want (it is not necessary to leave it in a proper dock station) and then the system will automatically define the best route for a truck to pass in every location where the bikes were dropped and take them to the correct places, made him think that, at the end, there is not a standardized way to evaluate and define what a Smart City is and the fancy expression “Smart City” depends not just on the advanced technology the city has(is) implemented(ing) but mostly on the perception citizens had/have with those initiatives.

In the Ljubljana case, one more reason which take them to claim themselves as a Smart City is because, for example, one of the actions the mayor took, was closing downtown to the passing of cars but at the same time maked possible (for youngers to hang out or to the elders to go to the restaurants) to order a lift in an electric vehicle, that the city has available for free, so the local economy does not get any negative impact because of the initial decision and citizen’s life remain equal.

Although this is a pretty recent subject (most part of the scientific literature available is from the last five to ten years), the Smart Cities’ theme is in vogue and getting more and more people and experts sharing ideas about it, however, until now we have not seen being discussed what could be a standardized way to evaluate cities and what takes to cities become Smart and what KPIs can be used to support this analysis, taking into account citizens’ perception.

1.2 Scope, objectives and structure of the document

Because of the globalization we have been testifying and all the emerging problems from it, like the loneliness of the old people and the forgetfulness of the disadvantaged, this document tries to better understand if the journey that cities are leading on the introduction of new technology on the citizens' daily life, are taking into account the quality of citizens life's perspective as the prime objective.The main objective of the present work is to have an optimized tool to evaluate the Smart City index in every city, taking into account citizens' perspectives and protecting their interests.

Although there were already taken several studies to identify the internal Smart City index in some countries like Italy (PA Forum, 2017; Siemens, 2017), Spain (IDC 2017) or Portugal (Inteli, 2017; IDC & NOVA IMS, 2015) with some of the KPIs considered in sustainable city assessment frrameworks by ETSI, ISO, ITU, among other, until this moment there is not a standard tool to differentiate the "Smart City level" of the different cities around the world taking special attention to citizens needs and interests.

"The way forward today is a community-driven, bottom-up approach where citizens are an integral part of designing and developing smart cities, and not a top-down policy with city leaders focusing on technology platforms alone," said Bettina Tratz-Ryan research vice president at the international research firm Gartner.

In the following chapter, it is analysed what is already written in the literature, perceiving what is the current state of the art both in terms of literature and in terms of actual facts observed. In its subchapters it has been made a detailed analysis of the theme, pointing the discussion over the concept, the Smart City areas/verticals of primarily focus, the concept of Urban Platform, the importance of promoting standards for systems integration, the openness of data to fight against vendor lock-in, the IoT networks and connectivity and an overview about the rankings/indexes which already are been using. Based on the data gathered from the reports of the entities who have delivered several studies on behalf of this theme, the aim of the chapter 3 ("Methodology"), first is to try to provide an overview about the initiatives which are happening in the different parts of the globe as well as demonstrating some Smart City use cases/solutions and then perceive what are the Key Performance Indicators used by the reference entities to evaluate the Smart City level of each city. After that analysis, it will be driven an inquiry to understand what the Smart City concept represents to citizens and also the level of importance people give to each KPI and its respective Sub Dimension on behalf of their thinking about what must have a bigger value (bigger coefficient associated) on the Smart City Index final equation. Results will be collected and analysed and conclusions will be taken from it in the final chapters.

2. State of the Art

In the past, the idea that a city could be “smart” was far from our reality and pointed on the media as science fiction. With the increasing of devices worldwide and with the increase of the embedded intelligence into those devices, lead us to say that Smart Cities are a new reality, and an objective that must be outlined from cities’ ambition.

“It is hard enough to find a good definition for smart cities but even harder to find a trustworthy description of what it takes to become a smart city” (Van Den Bergh and Viaene 2015)

First of all, we need to go over the concept to better understand what a smart city is, starting with an overview about the Internet of Things (IoT). Only that way it will be possible to study and define the line that separates those cities from the “normal” ones.

This chapter was divided in two, to separate what is the state of art based on what the literature has to teach us and what the initiatives that are being taken into account throughout the globe and the facts we can observe from that.

2.1 State of the Art based on the Literature

From the overview about the Internet of Things area until entering into the Smart Cities theme with the study over the concept and the identification of the areas that constitute a Smart City and rankings already used to measure the Smartness level of a city, the aim of the present subchapter is to give enough material to the reader about what is already written in the literature and how was its evaluation during the recent years.

2.1.1 Internet of Things – The basis for Smart Cities

According to Friess and Vermesan (2013) the IoT “is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services and reach common goals.”

Over the past years, the common strategy of cities was to collect data with non-digital and non-efficient methods, analyse it “offline” and take actions late. With the technologies for Smart Cities being developed, Cities had to fast try to update their infrastructure to be able to deploy them to be capable of having a real time monitoring, helping city officers acting almost at the exact moment they gather the data.

"Thus, there has been an increase in the request for embedded devices, such as sensors, actuators, and smartphones, leading to a considerable business potential for the new era of the Internet of Things, in which all devices are capable of interconnecting and communicating with each other over the Internet." (Rathore, Ahmad, Paul, & Rho, 2016)

IoT is "a radical evolution of the current Internet into a ubiquitous network of interconnected objects that not only harvests information from the environments (sensing) and interacts with the physical world (actuation/command/control), but also uses existing Internet standards to provide services for information transfer, analytics, and applications" (Association Institut Carnot, 2011)

The Internet is no longer a network of Computers, it is a network constituted by millions of connected devices and embedded systems. In a general perspective, IoT allows not only the interoperability between devices but also to have low power energy consumption networks so sensors and the rest of the devices can be connected for much more time with less power consumption involved. "Wireless sensor networks (WSNs), as the sensing actuation arm of the IoT, seamlessly integrates into urban infrastructure forming a digital skin over it. The information generated will be shared across diverse platforms and applications to develop a common operating picture (COP) of the city." (Jin, Gubbi, Marusic, & Palaniswami, 2014)

It is not just a matter of acting effectively in real time, IoT is also the base for urban planning of Smart Cities. Having historical integrated information gathered from the different devices allow cities to also take future actions according to this information.

2.1.2 Smart City

If we asked an auditory, full of people who have been actively working somehow on this subject, of what a Smart City is and what defines if a certain city is or is not smart, we would have a discussion for the following days.

One of the first persons exploring this theme said: "The validity of any city's claim to be smart has to be based on something more than its use of information and communication technologies (ICTs)". (Hollands 2008)

The fact that the population is growing fast demands that services and infrastructure must be thought to fulfil the needs of inhabitants.

The Smart City term was used for the first time in the 1990s. At that time the focus was on the importance of new ICT with regard to modern infrastructures implemented in the cities.

As a result of the expansion of the cities, both in the area as in the number of inhabitants, city decision makers have sought to find solutions capable of responding to the needs, related to power supply, traffic, and waste management in order to increase the quality of life for its residents and users. The term Smart City comes from the interactions mentioned above and the setup systems to manage them in the most efficient way. To be smart, a city does not need the state of art technology but the promotion of the interoperability between the various verticals of the city.

The Smart City concept appeared a long time ago, in the 20th century, to name the megalomaniac projects designed and implemented in those times, and has been changing from the technical approach to the people-oriented approach through the years. It is no longer a matter of deploying the technology. Going through the below definitions it is noted that over the years the focus passed from the technology itself to the purpose of what this technology was deployed.

Thus, we may adopt the definition of the IDC (International Data Corporation) that defines a smart city as "a city which has declared the intention to use information and communication technologies to transform the modus operandi in one or more of the following areas: energy, environment, government, mobility, buildings and services. The ultimate goal of a Smart City is to improve the quality of life of its citizens, ensuring sustainable economic growth ".

To have a clear view, below (Table 1) it is made an overview of the Smart City concept over the years.

Concept	Source
“A city which combines endowments and activities of self-decisive, independent and aware citizens”	(Giffinger 2007)
“A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish in their own lives”	(Rios 2008)
“Smart cities will take advantage of communications and sensor capabilities sewn into the cities’ infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone”	(Chen 2010)
“Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals.”	(Thuzar 2011)
“A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains.”	(Nam and Pardo 2011)
“A city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring”	(Guan 2012)
“Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centres that are at once integrated, habitable, and sustainable.”	(Barrionuevo et al. 2012)
“Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality”	(Bakıcı et al. 2012)
“A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as “green” referring to urban infrastructure for environment protection and reduction of CO2 emission, “interconnected” related to revolution of broadband economy, “intelligent” declaring the capacity to produce added value information from the processing of city’s real-time data from sensors and activators, whereas the terms “innovating”, “knowledge” cities interchangeably refer to the city’s ability to raise innovation based on knowledgeable and creative human capital.”	(Zygiaris 2013)
“A smart city utilizes ICTs in a way that addresses quality of life by tackling urban living challenges encompassed by more efficient utilization of limited resources (space, mobility, energy, etc.)”	(Jin et al. 2014)
“provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration amongst different economic actors and to encourage innovative business models in both private and public sectors”	(Marsal-llacuna, Colomer-llinàs, & Meléndez-frigola, 2015)
“a smart city is a place where traditional networks and services are made more flexible, efficient, and sustainable with the use of information, digital, and telecommunication technologies to improve the city's operations for the benefit of its inhabitants.”	(Mohanty, Choppali, and Kougianos 2016)
“what it entails in terms of smart applications holds some potential for sustainability—if astutely leveraged in the needed transition towards sustainable urban development. In other words, the concept of smart city provides solutions and approaches that can make sustainable cities smartly sustainable—if driven by a long–term planning approach that centers on sustainability. ”	(Ahvenniemi, Huovila, Pinto-seppä, & Airaksinen, 2017)
“smart city act as a composition of other forms of urban environment management strategies.”	(Nathali, Khan, & Han, 2018)

Table 1 – *Evolution of the Smart City concept and its modification throughout the years.*

2.1.3 Smart City Architecture

In a brief way it is also always important to understand the ecosystem and how the information is gathered and provided (Figure 1).

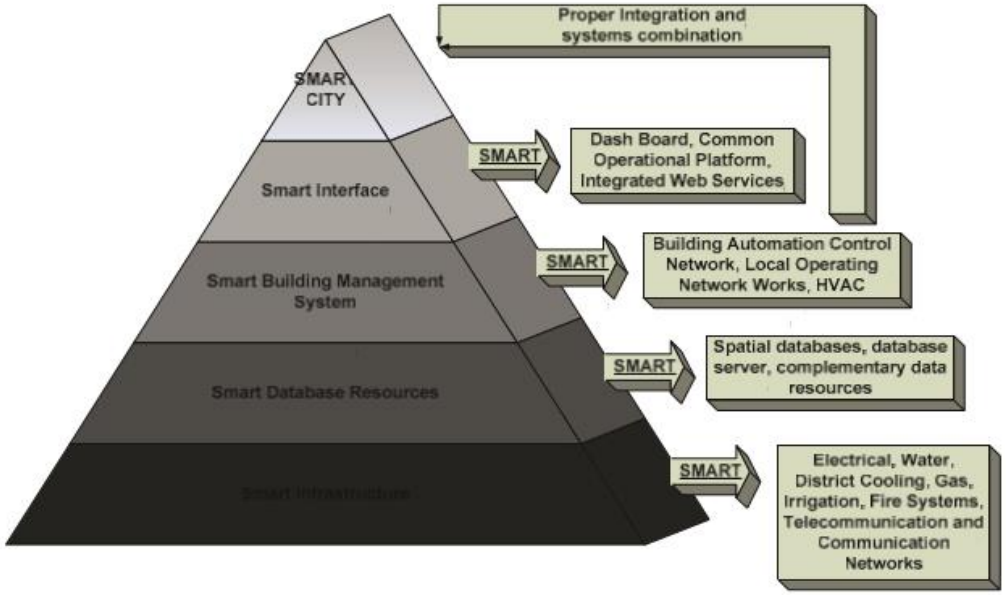

Fig. 1 - *Smart City Development Pyramid to demonstrate the different layers a Smart City must be built on.*

The connectivity of the different devices forms the basis of every single city claimed as Smart City. That happens because the concept of being smart is related to the better use of the information gathered from devices (sensors, cameras, etc…), usually through IoT networks as Sigfox, LoRa and Narrowband IoT or even through 3G / GPRS / GSM or Wi Fi (underlining the importance of having public infrastructure to cover the cities), to up layer horizontal platforms which purpose is to aggregate, manage and provide the data through reports to help their decision makers in matters of e.g. urban planning and citizens to access valuable information for their daily life (through web portals, mobile applications, etc…).

On the top of the objectives to become a Smart City is the possibility to be able to have a unique platform where city administration can access all of the information that is been gathering through their devices and infrastructures. Some of the more attractive and innovative opportunities identified in many smart city pilot projects involve working across different organisations within a city – mobility and environment, energy and mobility, environment and healthcare for example.

According to Luis Jorge Romero, General Director of The European Telecommunications Standards Institute (ETSI) “A smart city approach requires truly horizontal thinking, looking

beyond sectoral silos in order to re-imagine both existing and future systems, create new processes and interactions, and migrate towards new forms of digitized service delivery. With an integrated plan, the same layers of infrastructure can be shared between multiple services which were previously managed (expensively) in separate vertical systems".

If a Smart City strategy is taken without thinking in the future, horizontally, the integration of different applications/verticals will be a really difficult problem cities will have to face to use the entire information, due to the different standards and ways to gather the information from each application.

Instead of having custom-built integrations, having a higher layer comprising a set of services that allow applications to get data from multiple sources allows the integration of smart city services, increasing the potential to use and re-use data.

"A unifying information management platform delivers a capability across application domains critical to the city." (Jin et al. 2014)

In Figure 2, it is an example of the control centre which cities are intending to adopt with the cross and integration of the data gathered from the different sources and verticals, to help city decision makers having a more clear and integrated view in real time about what is happening in their cities.

Fig. 2 - *Istanbul Municipality presenting at Intertraffic Amsterdam 2018 its Smart City Management dashboard.*

This objective is also the biggest challenge cities will face, because of the number of verticals a city has to take into account, and the amount of companies with different technologies, standards, ways of thinking and strategies of each one of them, is easy to understand the difficulty behind the aggregation and correlation of this amount of data. “A unifying information management platform delivers a capability across application domains critical to the city. While large volumes of data collection and interpretation are already performing at different levels within city councils using manual and semi-automated methods, it is mostly in isolation.” (Jin et al. 2014)

In this case, tools as Machine Learning and Big Data are the key, as well as the open and specific standards the city itself has to promote into its ecosystem in order to be able to every element of this network be able to connect and talk with each other.

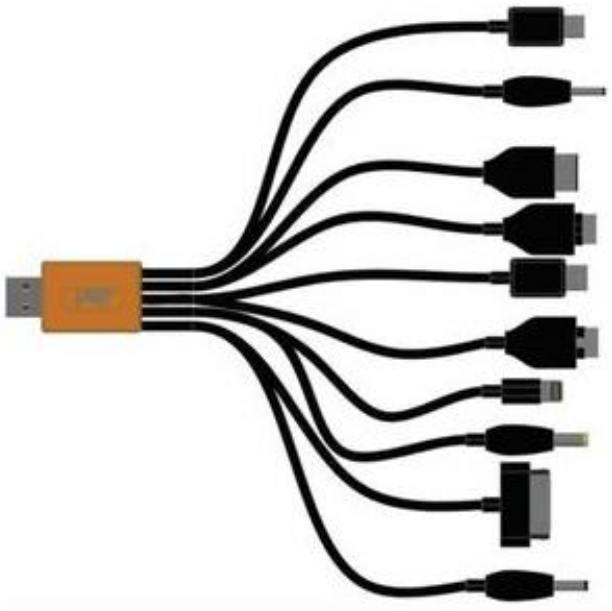

Fig. 3 – *Comparison of the USB multi-adapter with the interoperability/integration of the different verticals of the city.*
Source – Google "10 in1 to USB"

If we think on the different devices and cell phones that exist in the market and that almost every one of them has a different charger, imagine if it could be possible to have a unique charger for all brands (Figure 3), it would not be much easier? The answer is, of course, but how the brands would make money and guarantee the engagement and the loyalty of their customers?!

Cities must take this question very seriously, not because of cell phones but because of all the technology they have for each one of the different areas. If the several technologies aren't interoperable and do not "talk" to each other how can cities take and analyse all the important information they are gathering from the different sources of data? Imagine of having in your bag a charger with 10 different exits or 10 different chargers, what would be the best option? So the main word here is interoperability. How can we assure interoperability? One of the answers is "obligating" companies to adopt the same standards the city is promoting. And it is at this point that appears entities like FIWARE.

Fig. 4 – *Yasunori Mochizuki, Senior Vice President of NEC, at FIWARE Global Summit in Oporto, presenting the ecosystem surrounding FIWARE.*

FIWARE is an open source community, operating on a global scale and governed by the FIWARE Foundation, whose mission is to create "an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that will ease the development of new Smart Applications in multiple sectors" FIWARE. This community was originally funded by the European Commission and intends to support entrepreneurs in Europe via the Startup Europe initiative, encouraging any type of stakeholder (such as small and medium-sized enterprises, universities and cities) to get involved. Currently, more than 100 cities from all over the world use FIWARE standards, focusing on the needs of cities and communities when creating a Smart City market. In order to make it all possible, the community has a tool named FIWARE platform that adds value by putting together a set of "ready-to-use" micro-services, making the development and enhancement of Smart Applications easier. The open standard APIs provided allow "to enable the connection to the Internet of Things, support a smart and context-aware behavior through the real-time processing of data and media content at large scale as well as the analysis of Big Data, or the incorporation of advanced Web-based User Interface features (e.g., Augmented Reality or 3D visualization), among others." Home-FIWARE (2018).

2.1.4 Smart City areas and rankings

The basic definition is the main conditioning of every ranking. Because of the fact that, as we have seen, there is not a standard definition yet of what is a Smart City, there is not also a

unique matter of defining the areas which constitute a Smart City. At the same time that for example, while the Ranking of European Medium Sized cities defines 6 areas: Smart Economy, Smart Mobility, Smart Environment, Smart People Smart Living and Smart Governance, the IDC consulting uses only 5: Smart Governance, Smart Buildings, Smart Mobility, Smart Energy and Environment and Smart Services.

Despite this, to cover all the areas of action, Smart Cities can be split into 10 different sub areas: Smart energy, Smart building, Smart mobility, Smart technology, Smart healthcare, Smart infrastructure, Smart governance, Smart education, Smart security and Smart Citizens.

Smart energy	"Integration of renewable energy production, infrastructures and consumption. The use of Smart Meters permits energy service providers to remotely monitor the consumer's consumption and even connect/disconnect power." (Staff, E 2018)
Smart building	"Any structure that uses automated processes (sensors, microchips, etc…) to automatically control the building's operations including heating, ventilation, air conditioning, lighting, security and other systems." (What is a Smart Building? | Building Efficiency Initiative | WRI Ross Center for Sustainable Cities 2018).
Smart mobility	"Use of innovative and integrated technologies and solutions, such as low emission cars and multimodal transport systems to reduce the number of congestions and number of traffic accidents." (Smart Mobility 2018)
Smart technology	"Every device and infrastructure such as our home, office, mobile phone, and car are connected on a single wireless IT platform". (IGI Global 2018)
Smart healthcare	"Use of eHealth and mHealth systems and intelligent and connected medical devices to detect anomalies and be able to respond efficiently to them remotely." (ActiveAdvice 2018)
Smart infrastructure	"Intelligent and integrated systems that manage energy grids, transportation networks, water and waste management systems, and telecommunications." (What is Smart Infrastructure? - Intelligent Sensor Networks Conference 2018).

Smart governance	"Policies and digital services from the government that help and support the adoption of green and intelligent solutions through incentives, subsidies, or other promotions. The technology used as a tool to facilitate and support better planning and decision making, improving democratic processes and transforming the ways that public services are delivered." (Collins Dictionary 2018)
Smart education	"Is the changing and reforming of the paradigm of education to the specific needs of the 21st generation." (ByeongGuk Ku 2018)
Smart security	"Solutions such as video surveillance and managed security services that are designed to prevent and detect crime before it happens, protecting people, properties, and information." (Cagliero, Luca et al. 2015)
Smart citizens	"With bottom-up initiatives, Smart citizens will take an important role in cities future development." (Allessie, D. 2018)

There were already made empirical studies in several countries to try to define the Smart City index.

As a matter of example, on one hand, as it was mentioned above, in Portugal, Inteli for the 6th consecutive time has identified the Portuguese Smarter Cities taking into account 5 dimensions, 24 sub-dimensions and 93 indicators (Inteli, 2017; IDC & NOVA IMS, 2015). In Italy, the annual report produced by FPA, a company of the Digital360 group, the ICity Rate 2017 identified and analyzed 15 urban dimensions and 113 indicators (PA Forum, 2017; Siemens, 2017). In Spain, IDC has used 5 dimensions and 94 indicators to evaluate the top Smart Cities in the country (IDC, 2017). Navigant Research who has assessed UK cities and organize them in the different categories: Leaders, Contenders, Challengers and Followers, according to the results obtained in the evaluation of each dimension/KPI of the Smart City Index.

On the other hand, Forbes has shared for another year the study taken by the IESE Business School (University of Navarra) which claimed New York City has the Smartest City on the planet in 2017. The second place went to London and the third to Paris. The remaining top 10 cities are Boston 4th, San Francisco 5th, Washington, D.C. 6th, Seoul 7th and Tokyo 8th, Berlin 9th and Amsterdam 10th.

The IESE Cities in Motion Index (CIMI) has empirically assessed “the cities in 79 indicators across to 10 key dimensions: economy, human capital, technology, the environment, international outreach, social cohesion, mobility and transportation, governance, urban planning, and public management.” (Forbes, 2018)

In Figure 5, can be seen the results of this index for the cities of Oporto and Lisbon.

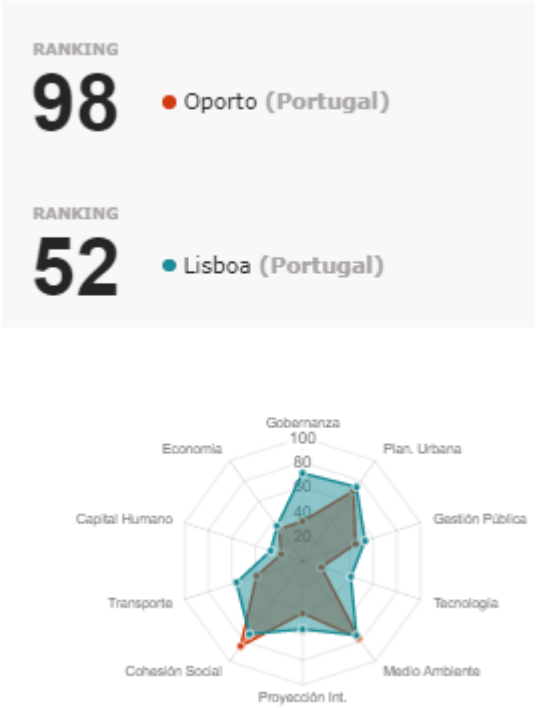

Fig. 5 *- Lisbon and Oporto ranking results on the Cities in Motion platform (IESE Cities in Motion Index 2017 | Cities in Motion 2018).*

The most known rankings are Cities of Opportunity (PricewaterhouseCoopers 2014), Hot Spots 2025 (Economist Intelligence Unit 2013), Global Power City Index (Mori Memorial Foundation 2015), europeansmartcities (Vienna University of Technology 2015) and Global Cities Index and Emerging Cities Outlook (A.T. Kearney 2016) which says that “... there is not yet a standard for what constitutes a smart city”.

2.2 State of the Art based on actual facts observed

After having the perception of what is written in the literature is also important to get an overview about the main Smart City initiatives throughout the globe and the use cases that are being implemented. Because of the fact that each city and each city administration is different, the deployment of solutions and the though use cases as a way to improve citizens’ quality of life depend on the region and culture associated.

This subchapter begins with an overview of how the theme of Smart Cities has started and why it is so important to “become Smart”.

2.2.1 Why it is so important to “become Smart”?

Let us imagine the following scenarios:

Scenario 1) - Every day, thousands of commuters use their car as the preferred means of transport, increasing city’s traffic congestion and, consequently, environmental pollution. One of the reasons for this problem lies in the current transport public systems and traffic planning which are forcing commuters and drivers to choose their cars over the transport public. Besides having direct consequences on the time spent and on the fuel consumed, it increases emissions of greenhouse gases and ultimately reduces the citizens’ quality of life. Regarding social and environmental problems, decision makers have identified several problems in current traffic conditions, such as:

- Inefficient management and enforcement of the traditional traffic systems, reducing the response time of new policies;
- Out-of-date systems which do not embody ICT features, making it difficult to take a more accurate management decision;
- Unsuitable interaction with decision makers through data sharing and clear communication, diminishing the response time to redirect the traffic flow for less congested roads.

In regards to the benefits of having a Smart Traffic deployed (with counting sensors or cameras), it is possible to highlight the access to real-time traffic information as the most important of all, since it allows to understand the commuters patterns and behaviours, improving the management and enforcement capabilities of the traffic managers.

Scenario 2) - According to World Health Organisation (WHO), 92% of world population live in areas where the air pollution is above WHO limits, being responsible for augmenting acute and chronic diseases worldwide, such as heart disease, stroke, respiratory disease and cancer. Moreover, the same organization has highlighted that one in eight premature deaths worldwide is due to air pollution.

All main sources of air pollution are well known. Households, factories, transportation, natural disasters and agricultural activities are the main sources of particulate matter; ozone; nitrogen dioxide; sulfur dioxide; nitric oxide; carbon dioxide; carbon monoxide; methane; volatile organic compounds; ammonia; among others. Since Cities present a very diversified economic activity,

it becomes necessary to further studied and understand the air quality and atmospheric conditions of them, as well as the patterns, common behaviours and others vital aspects related to the environment.

Most cities worldwide have air quality stations deployed, however, they represent a high budget for municipalities due to their maintenance costs. The modernization of the equipment used for monitoring the air quality and its deployment on strategic locations across the city could not only help to monitor, in real time, the air quality and the air pollutants but also prevent a regression of the effort made to deal with the problem. Through the installation of air quality system that can tell, in real time and automatically what is in the air, without e.g. needing to be analysed in a laboratory, the entire process becomes easier, simpler, faster and cheaper.

If we aggregate the scenarios 1) and 2), the traffic with the air quality data, imagine the powerful tool that decision makers have in hands for matters of urban planning (and we are just considering two verticals of the areas of mobility and environment).

A city that wants to make itself "smarter" is a city that is putting its efforts in being more efficient, sustainable, equitable and liveable, mitigating the problems generated by the urban growth and quick urbanization. Smart Cities came from the combination of the need to solve the problems that cities are facing and the opportunities offered by the digital revolution.
90% of Global Data has generated only two years ago. 50 to 100 billion devices will be connected to the Internet and the number of Smartphones will be around 2 to 6 million (EC, 2018). According to Figure 6, the number of things connected to the Internet exceeded the number of people on earth in 2008.

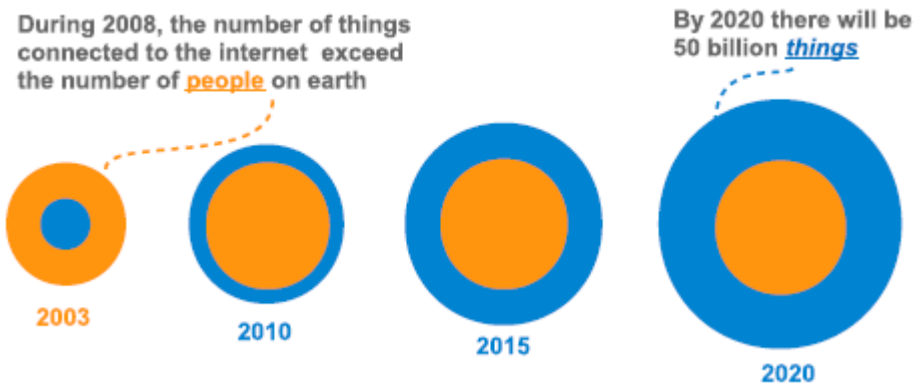

Fig. 6 – *Evolution and expectancy of the growth of "things" connected to the Internet.*

Cities' population is growing fast. It is expected by 2050 that 70% of the world's population, over six billion people, will live in cities and surrounding regions. This will take cities to face problems and challenges associated with the process of urbanization, climate change and social exclusion (IDC 2012).

These pieces of Earth that only represent only 2% of the entire surface with more than 50% of World's population are responsible for 70% of energy consumption and 75% of carbon emissions (UNEP 2011).

The most recent study from the UN tells us the prediction for the world's population on 2017, 2030, 2050 and 2100 (Figure 7).

Region	*Population (millions)*			
	2017	*2030*	*2050*	*2100*
World	7 550	8 551	9 772	11 184
Africa	1 256	1 704	2 528	4 468
Asia	4 504	4 947	5 257	4 780
Europe	742	739	716	653
Latin America and the Caribbean	646	718	780	712
Northern America	361	395	435	499
Oceania	41	48	57	72

Fig. 7 – *Population prospects by UN for 2017, 2030, 2050 and 2100.*

The urban growth (the actual status can be seen in Figure 8) that has been witnessed in the last decades all over the world, as a result of economic development and globalization, have resulted in the creation of interdependent relationships within the cities. These lead to cities becoming messy, disordered and complex systems requiring increasingly greater planning.

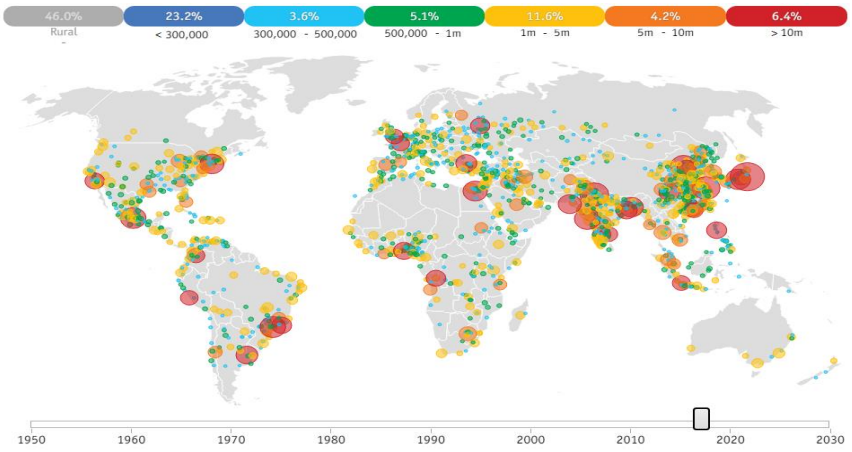

Fig. 8 – *World's population distribution.*

Ensuring sustainability and livable conditions to the next generations is the hardest challenge cities have in hands. “Making a city smart is emerging as a strategy to mitigate the problems generated by the urban population growth and rapid urbanization” (Chourabi et al. 2012).

Despite the fact that some individuals use this fancy expression as a matter of marketing only to catapult their ecosystem on the media, what is really relevant to be mentioned about the difference between a City and a Smart City is the fact that the first one is not focused on providing an efficient use to its existing infrastructure and the information gathered from the different components/devices of the ecosystem. A Smart City is seen as the upgrade of a City imposed by the primary objective of improving the quality of life of its citizens.

The objective of smart city initiatives has to be addressing and improving citizens’ quality of life. If we make a comparison with Football, a coach does not define the tactics for his team before having chosen and firming all the players, his ideologies have to adjust to the group of people he has in front of him to better use their skills in favour of the team results. Only that way he will succeed in its task and make happy all the stakeholders.

Because of the fact a city is composed of different people, with different ages and perspectives, the introduction in every day’s life of a new technology has to take into account the reaching of the most people needs possible (e.g. there are persons who have not smartphone, we have to take into account in all of them). According to the different realities, “if we want to understand better behaviour and motivation of individual citizens and to be able to model such behavior, we must address the differences in perception of quality of life” (Pribyl and Horak 2015).

2.2.2 Smart Cities in the World

Based in different reports and public news, in this subchapter, it is given to the reader an overview about the status of the Smart Cities initiatives throughout the globe, taken from the analysis of several reports and sources.

Although the smart cities market has a vast potential for IoT solutions, it is a slow market with many different challenges. Several cities already found solutions in the form of new measures and technologies. The local and regional needs are shaping the way cities look to themselves, leading to the deployment of more and more IoT technologies for a wide variety of different uses cases.

In 2012, there were 143 Smart City projects worldwide: 47 in Europe, 46 in America, 40 in Asia and 10 in Africa and Middle East (Lee & Hancock 2012). Based on the report done by the Business Insider Intelligence report of 2016, in the EU cities, the environmental sustainability is what is leading them to a rapid implementation of IoT technologies. In Central and South

America, road congestions are a major problem as well as infrastructure's resilience to extreme weather events. Real time source solutions are being used to solve those problems. In Africa, although the smart city development is precocious, networks' next generation will provide the needed connectivity to create the infrastructure for smart city projects. When it comes to Asian cities, allocating IT human resources to manage Smart City projects is a true challenge. Regarding North American cities, although they are always well represented in the several rankings the deployment of IoT solutions is way behind EU cities. (Intelligence, B. 2018)

2.2.2.1 Europe

For the EU, smart cities are a priority on the political agenda. In order to facilitate the development of future urban systems, Horizon 2020 aims to support the development of smart, sustainability-oriented technologies in cities in several areas (such as energy, transport and information and communication technologies) and to create strategic partnerships between European cities and industry.

Copenhagen, Stockholm, Munich, Berlin and London are the European leading technology cities due to their investment in R&D per capita of more than 800€.

The main European technological developments are in the Nordic countries – Denmark, Finland, Sweden and Norway.

Their focus is mainly on using renewable energy to be able to better manage the usage of energy, to improve resources management and to innovate in the areas of transport and urban mobility.

Helsinki has the ambitious target to eliminate traffic by 2025 by integrating the different vertical layers of public transport, public bicycles and private cars into the same horizontal project through a personalized route provided to the citizen taking into account real time traffic conditions. (Greenfield, A. 2018)

Similar to Helsinki, Copenhagen wants to create a smart traffic system in order to improve the movement and safety of citizens and to reduce gas emissions. By smartly controlling traffic lights (based on the number of pedestrians, drivers and, cyclists that are circulating at a specific time), the city intends to improve the flow of traffic. Public transports will be able to communicate with the system warning about delays or too many passengers on board. Thus, through the use of Bluetooth and with the integration of beacon (as a matter of identification that that specific vehicle is a bus), they are provided with an extended "green light" when they are approximating a traffic light, reducing this way the route time in more than 30%.

The German capital, Berlin is trying to combat the use of a personal vehicle for the electric car. For that, they are currently installing a network of stations to recharge the batteries in the urban infrastructure (e.g. streetlights). The city is also prohibiting certain types of vehicles (mainly the old ones, and the ones with gas and diesel) to circulate in some of the city' areas. With these measures, the city aims to encourage the use of these new vehicles and reduce CO2 emissions into the atmosphere.

The aim of "Amsterdam Smart City" initiative is centred in the area of sustainability and energy since it is intended to reduce CO2 emissions by 40% in 2025 and by 70-80% in 2040 by producing one third of the needed energy using renewable energy sources. 30 pilot projects covering the different areas compose the project. The ones that obtain the best results are implemented on a larger scale. This initiative is/will transform the city of Amsterdam into a living lab, where intelligent technologies are deployed and tested to get results to study if it can serve as an improvement to the quality of citizens life. The City of Amsterdam has also been promoting the open data concept, launching the "Apps for Amsterdam" competition for the presentation of data-based solutions for the city, under the umbrella of the concept of open innovation.

The situation in Spain is very promising, mainly due to the Spanish network of smart cities (RECI), made up of 60 municipalities.

Barcelona has become a reference in the world of IoT thanks to the disruptive projects they have deployed over the years and to the institutional momentum and holding of international conferences, such as the Smart City Expo World Congress and the IoT Expo World Congress.

As it happens in Amsterdam the aim of the "Smart Santander" project is to transform the city into a living laboratory, a space dedicated to the research and experimentation of new technologies and applications with the purpose of improving the quality and management of services provided to citizens. With the open data mentality (as it was mentioned in the case of Amsterdam) the city makes its data available so that programmers can create applications that can mainly help citizens. Calls for proposals are regularly open so that new services can be tested on the "Smart Santander" platform. Already 12,500 sensors have been installed throughout the city allowing real-time information.

2.2.2.2 America

US cities (New York City, Boston, San Francisco, etc…) lead most of the rankings which purpose is to evaluate the Smartest Cities in the World.

An investment of more than 150 million euros (50 million in public funding and more than 90 million in counterpart funds for advanced transport technologies) in Smart Cities Solutions was

announced by the US Department of Transportation. The objective of this investment is to help to solve traffic congestion and improve the safety of drivers and pedestrians.

In 2024, Latin America will have 158.9 million machine-to-machine connections (M2M), with Brazil and Mexico concentrating almost 64% of this market. The presence of Brazil and Mexico at the top of the Latin American list is explained by the organized wireless network infrastructure they have, unlike the other countries of the region (“Latin America To Reach 159 Million Machine to Machine IoT Connections by 2024” 2018).

2.2.2.3 Asia

The disparity between cities like Singapore, Seoul and Hong Kong, and cities like Beijing, Jakarta and, Chennai is huge. The pollution level of Beijing is on red alert, Chennai is underwater for most of December and traffic from Jakarta is a chaos. (Tech in Asia - Connecting Asia's startup ecosystem 2018)

Asia must figure out to deploy Smart City technologies to help to improve the conditions of living of its citizens and fight air pollution.

This because Asia must take the lead in building smart cities over the next century. With a forecast of 62 megacities (cities with more than 10 million people) by 2025, above the current 32.

Songdo, in South Korea, was a city built from scratch with an investment of more than 30 billion euros. This mega project is being watched closely by countries and cities around the world. The city features some of the most advanced technologies in urban development and planning reaching the main objectives of having almost 50% of the city as green spaces, smart building’s waste management, among others.

Similar to this project is one that is currently occurring in Masdar, expected to be completed in 2025, with an investment of more than 20 billion euros. "Masdar City" which will be the home of 40 thousand inhabitants is located in the desert 17 km from Abu Dhabi with about 700 hectares. Its major goal is to affirm itself as the first ecological city in the world, a zero carbon city. Some of the sustainability targets to achieve are: 100% of the energy supplied by renewable sources; almost 100% of recycled waste; water consumption 50% lower than the world average, and all wastewater reused. One of the goals of this city’s project is to establish a city without cars, favouring public transport and autonomous electric vehicles. (Has 'smart' Songdo been a success? 2018)

2.2.2.4 Africa

Connectivity (with attention the terrestrial fibre projects) is the critical infrastructure needed and the starting point for an intelligent Africa.

The South African National Development Plan identified the major cities committed to the challenge of foster the ideology of a smart city: Johannesburg and Cape Town, with Durban close by (Sidler, V. 2018). Johannesburg is committed to implementing smart utilities. Cape Town, who has launched the “Smart Cape Project” to ensure that all citizens had free access to basic information and communication technologies has already invested nearly 13 billion euros, with additional funding from the Western Cape government of 800 million euros for broadband infrastructure and more than 1.5 billion euros for the Digital Inclusion Project (Wi-Fi). (Digital Cape Town. 2018)

2.2.2.5 What about Portugal?

“Portugal is the 70/30 country” an expression used by a relevant person of the National Association of Portuguese Municipalities, to describe the state of our country in terms of urban population. 70 % of the Portuguese population leaves in 30% of the territory.

The results of the Portuguese Smart Cities Index 2015 study, conducted by IDC and New IMS, demonstrate that out of the fifty municipalities with a population of over fifty thousand inhabitants, selected and analyzed, only four are in considered as “top”. The municipalities considered as the most intelligent of the national territory, leading the ranking of Portuguese cities are: Lisbon, Oeiras, Porto, and Bragança. The investment that is being made on the quality of life of citizens and sustainable economic growth is the difference between the above four municipalities and the rest.

“Although they are not leaders, the 15 municipalities that comprise the group (Guimarães, Coimbra, Viana do Castelo, Barcelos, Cascais, Aveiro, Oliveira de Azeméis, Matosinhos, Leiria, Faro, Braga, Évora, Funchal, Valongo, and Loulé) have above average intelligence indicators. Lisbon, Almada, Beja, Loures and Évora are the cities best positioned in terms of mobility, due to the actions they have promoted in the areas of sustainable mobility, with a view to reducing emissions of greenhouse gases (GHGs) and improve the quality of life of citizens.” (Inteli, 2015)

In the year of 2017 the Government has launched an initiative named “Fundo Ambiental – Laboratórios Vivos para a Descarbonização (LVpD)” to permit cities becoming real Living Labs, giving 500 thousand euros to those who have present the most interesting projects on behalf of

the Smart City theme with the clear objective of implementing technologies to help the process of decarbonisation of cities. The Cities have presented proposals taking the necessary solutions to achieve their Smart City strategy. The aim of this budget is to test solutions (and their integration) for 10 months in a real environment.

In Table 2, it is possible to perceive what are the cities which will be able to establish these projects.

Name	Funding
Almada	€ 500 000
Maia	€ 500 000
Matosinhos	€ 499 122
Águeda	€ 360 656
Loulé	€ 409 093
Alenquer	€ 408 481
Seixal	€ 500 000
Mafra	€ 419 280
Braga	€ 400 036
Évora	€ 500 000

Table 2 – *Cities which won the opportunity to establish a Living Lab of real time data solutions with the funding provided. (Laboratórios Vivos para a Descarbonização 2018)*

In Portugal there already some initiatives regarding this theme as:

- "RENER" - Portuguese network of Smart Cities constituted by 43 municipalities dispersed throughout the national territory, which act as stages of development and experimentation of innovative urban solutions in real context, as living laboratories.
- Cluster Smart Cities Portugal - a platform of cooperation between companies, associations, universities, R&D centers, municipalities, public bodies and civil society;
- NAPM (National Association of Portuguese Municipalities) - Smart Cities section - The network composed by 124 municipalities (64% of the Portuguese population and 43% of the territory) aims to share experiences and good practices as well as develop joint projects (functioning as a living laboratory for testing and experimentation of innovative urban solutions)

"The use of Public Transportation after Smartphone's appearance has decreased 20% which took an increase of the tariff in 27%" said one of the responsible persons from the Porto Intermodal Transportation. He concluded that this is a serious problem, which Portugal will face in the upcoming years because people do not like to change their habits and if the price of gas is affordable, they will keep using the private vehicle to do their daily life.

If we think on the number of cars which every day are only used 5% of the day, for a distance of less than 10 Km and only used by one single individual, it is easy to understand all the potential that cities are missing in improving their results on air quality and traffic efficiency, among others.

Focusing on the technological point of view, information in real time can be a tremendous tool to assist decision makers on their decisions. The possibility of aggregating the information we gather from the several verticals of the city must not be underestimated.

The former Secretary of State and one of the coordinators of the Smart Cities Tour 2018 (Figure 9), said in Albufeira at the first event of the 2018 tour “imagine if the city is willing to start building a cycle path and knows already the routes that the citizens prefer to cycle, so it would be possible to restrict efforts and budget to those roads”.

Fig. 9 – *Smart Cities Tour 2018 launching.*

2.2.3 Overview of some Smart City Solutions and Use Cases[1]

Regardless of the area/vertical, the thinking behind every Smart City solution is in a device (it can be a sensor, a camera, etc...) capable of generating automatic data which will be collected (depending on the communication network it can be directly to the cloud or using repeaters and

[1] Note: All the pictures used in this chapter were taken from the solutions presentation possessed by the author for its daily work.

gateways with private protocols) for a software application/platform to manage, analyse and possibly integrate with other sources of data to generate valuable information for a specific purpose.

Fig. 10 – *Ubiwhere's/Citibrain's Smart City solutions for the different verticals presenting at the Portugal Smart Cities Summit 2018 in Lisbon.*

Through magnetic Parking sensors, surface (Figure 11) or embedded, capable of detecting if a parking spot is available or not, it is possible to inform a driver which is leaving his home and wants to know the best route to go to the closest available parking spot of his office, about its real time occupancy. With the integration of the information gathered from the barriers of the private parking and their management systems and the data gathered from counting vehicles magnetic sensors (Figure 12), installed in the entries and exits of public parking lots, the city is able to provide the information to the drivers regarding the real time availability of every parking lot in indicative panels (Figure 13) installed in strategic places so the traffic can flow more efficiently. These sensors are also used to have historical data about traffic and understand the number of vehicles that entered and leave the Cities can also manage traffic lights automatically with this real time data information (from sensors or cameras) instead of the fixed time management system which they work right now.

Fig. 11 – *Surface magnetic Parking sensor*

Fig. 12 – *Embedded magnetic Traffic sensor*

Fig. 13 – *Indicative Panel*

The garbage collection process is very expensive. For every kilometre that is not made by the garbage collection trucks, it is a lot of money that is saving. With this mind, can be installed volumetric sensors (Figure 14 - Left) in the trash bins capable of monitoring the container's filling level and when this level overcome a certain threshold, an alert is sent saying that that specific container must be collected. The daily collection route can be optimized and planned according to these data, passing only in the containers that are ready to be collected at that time (Figure 14 – Top right). In Europe, there have been implemented a system in the containers (known as the "pay-as-you-throw" system) to permit citizens only open the cover of the container after the RFID reader accept the card of the family. This way it will be counted the number of times a certain household has used the container (Figure 14 – Bottom right), reflecting it in the price to pay at the end of the month for Waste tax (disassociating from the Water bill).

Fig. 14 – *Volumetric waste sensor and the optimized route generated by the data gathered from it. Pay-as-you-throw system and reading exemplification of the household card.*

Another real time data use case is the possibility to have noise sensors (Figure 15) installed in some areas to cities be able to design noise maps asked e.g. by the European Commission or to identify and mitigate the source of the complaints regarding the noise of the discos, clubs, and bars in the city centre. Air Quality low cost stations (Figure 16) can overcome the problem cities have of just having (in the most cases) one or two very expensive meteorological stations which although they are very precise, most of the times there is not made a proper maintenance and that leads to a useless source of data. Not mentioning the fact that we cannot gather real time data with it. With the low cost ones, cities are able to deploy a network capable of getting real time data about the different parameters, generating alerts and helping their administrators to prevent and take actions based on real data.

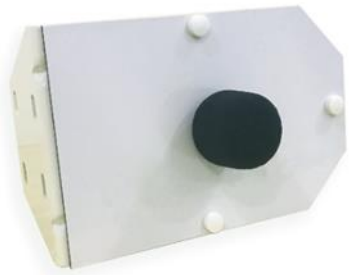

Fig. 15 – *Noise module*

Fig. 16 – *Air quality outdoor module*

In the future, will be the opportunity to add an additional component to the lamp posts to permit EV charging and the option to rent the post to mobile operators (neutral hosting) when 5G arrives (Figure 17 – Top left). Or even car sharing / pooling and bike sharing (Figure 17 – Top right) solutions (usually electric/or electrically assisted bikes) where it is given the opportunity to pick a bike in a dock station and the option of leaving it in any place because the system at the end of the day will generate a route so then a truck can pick the those “lost” bicycles as well as having the possibility to integrate those services with public and private transportation in a multimodal platform (Figure 17 – Bottom).

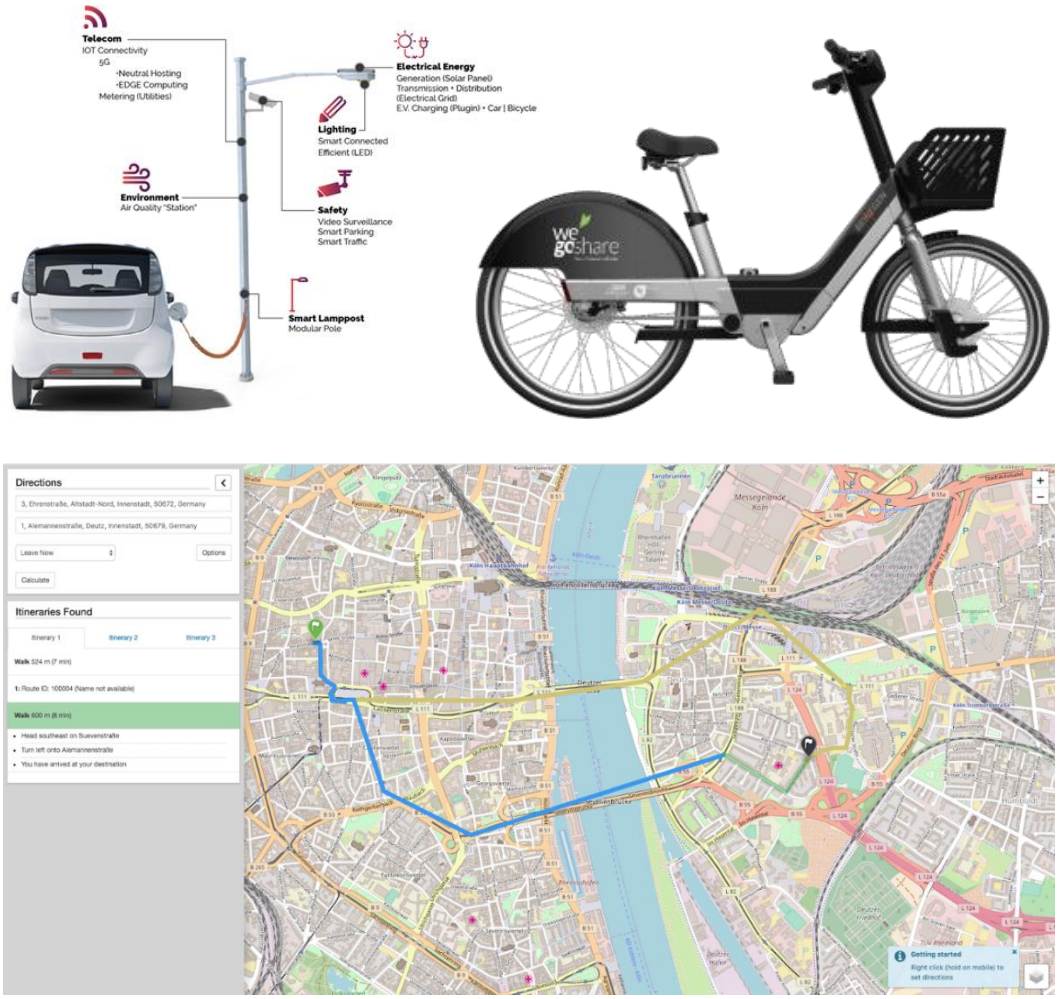

Fig. 17 – *A lamppost which is prepared to integrate an EV charging module, an electric bike and the dashboard of a multimodal platform.*

In the end of the day, the purpose of every Smart City initiative and solution deployed will be to provide to city officers not just data, but quality information (ideally in one single dashboard) to evaluate the current status of its city and that way be able to better plan and maximize its resources to provide to citizens better conditions of life.

The beauty of defining a Smart City strategy and the solutions needed to implement to fulfil that strategy is on the number of use cases and scenarios that can be taken into account.

3. Methodology

A Smart City must not be the used term to identify a city which has implemented the Smartest Solutions but the one which has provided the better living conditions for its citizens with the implemented solutions. The aim of this document is not to understand the advanced technology which has been deployed in the cities as it was the main focus of some of the empirical studies identified in the previous chapter, but how can these Smart Solutions improve the quality of life and which are the standards to measure that.

Like the finals we have at the school where it is given to every student of a specific class the same questions to answer, it is important to have a standardized way to compare cities. The result of it will depend of course on how much you have prepared yourself for that task or, in the case of a city, it is the development status of it. Therefore it is important to set a list of Key Performance Indicators capable of defining evaluation criteria with a common standard. This way we will be able to provide tools for the city administration to understand what are the missing gaps and the weaknesses of their city in order to have a clear vision on how they need to allocate their primary efforts to improve citizens' quality of life.

The clear objective of this chapter was to collect citizens' opinions about the Smart City theme and the value they think each KPI and Sub Dimension must have to calculate each coefficient in the final equation (through the arithmetic average).

First of all, it was collected and analysed the KPIs, Sub Dimensions and Dimensions which the reference entities have designed and are already been using and which are present in some ISOs and formal reports. After that, it was cut and added KPIs according to author's opinion (after several moments of brainstorming in congresses and also from the points rased by his colleagues at Ubiwhere) to, in the end, present the final KPIs to the respondents to evaluate and prioritize. The analysis of the results and the conclusions can be observed in the following chapters.

The inquiry of this Methodology has the major objective of collecting the points of view of citizens first regarding their understanding of what Smart City stands for and a couple more questions to perceive if their opinion is oriented to technological issues or not, and then get their answers of KPIs and Sub Dimensions prioritisation.

In summary (Figure 18), the following steps are:

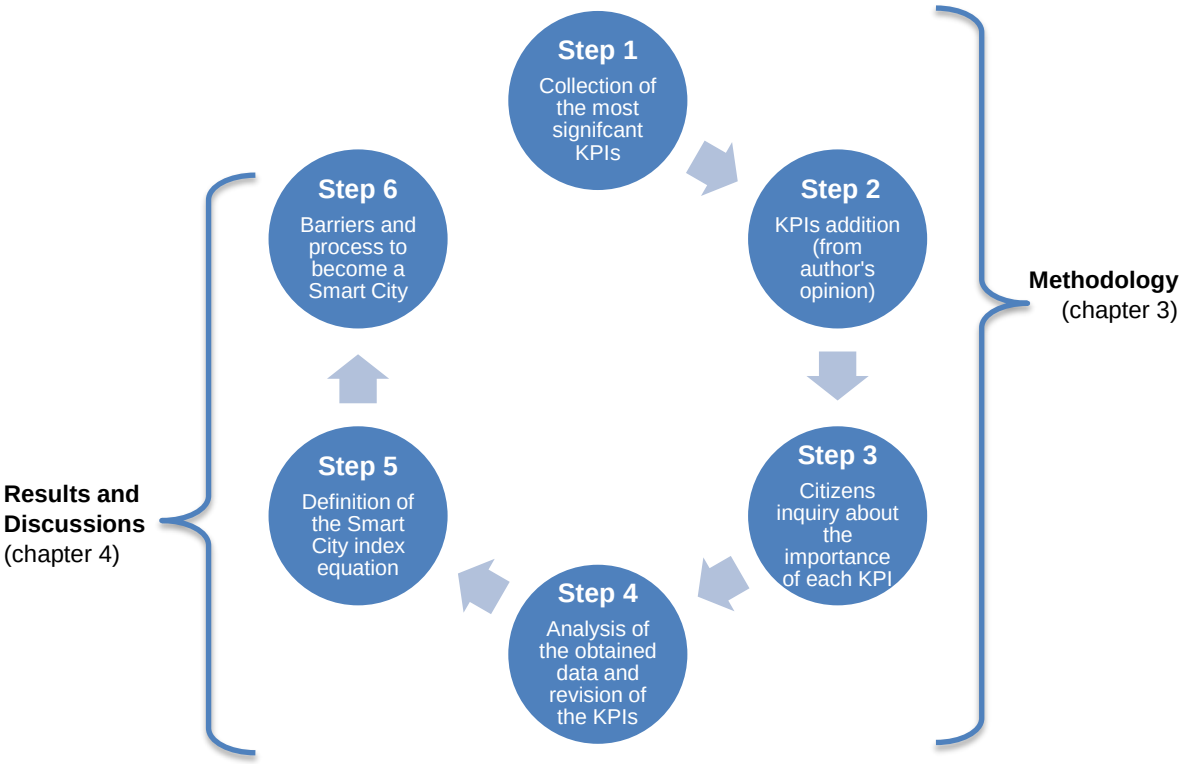

Fig. 18 *– Steps of the following Methodology lead by the author.*

Step 1 – Collection of the most significant KPIs

For the purpose of identifying an optimized tool to evaluate every city, first of all, we need to explore the Dimensions, Sub Dimensions and KPIs that are being considered and calculated by the entities related with the theme responsible for the definition of standards, as ISO[2], IEC[3], ITU[4], ETSI[5] or NIST[6], consider the primary division of a city and not the subareas of a Smart City, because the intention here is to define a standard way to define the Ranking Level of a City seeing the entire picture and not just focusing on the smartness technology they have implemented for each one of the Smart City areas.

The Smart City and Sustainable City assessment frameworks considered to get the KPIs were:

- European Smart Cities Ranking - (Giffinger, 2007)
- BREEAM Communities - (Planning & Stage, 2011)
- Triple-helix network model for smart cities performance - (Lombardi et al., 2011);
- Smart City PROFILES - (Profiles, 2013)
- Eurbanlab - (Eurbanlab 2014);
- ISO 37120 Sustainable development of communities - (ISO 2014);
- Reference framework for European sustainable cities - (Rfsc, 2014);
- City Protocol - (City Protocol Society 2015)
- CITYkeys - (Tno, Tno, & Tno, 2017)

This sad, the city can be assessed for 4 different major dimensions: People, Planet, Prosperity and Governance.

[2] International Organization for Standardization focus is to facilitate the international coordination and unification of industrial standards.
[3] The International Electrotechnical Commission is an international organization that prepares and publishes International Standards for all electrical, electronic and related technologies.
[4] International Telecommunication Union is the United Nations specialized agency for information and communication technologies – ICTs.
[5]The European Telecommunications Standards Institute is an independent, not-for-profit, standardization organization responsible for the definition of global standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.
[6] The National Institute of Standards and Technology, also known as the National Bureau of Standards, promotes and maintains measurement standards in the U.S.

1) People

Sub Dimension	KPI Title	Measurement Unit	Definition
Health	Access to basic health care	% of people services	Share of population with access to basic health care services within 500m
	Encouraging a healthy lifestyle	Likert scale	The extent to which policy efforts are undertaken to encourage a healthy lifestyle
	Life expectancy	# of years	Life Expectancy in the city
	Hospital beds	#/100.000	Number of in-patient hospital beds per 100 000 population
Safety	Traffic accidents	#/100.000	Number of transportation fatalities per 100.000 population
	Crime rate	#/100.000	Number of violence, annoyances and crimes per 100.000 population
	Police officers	#/100.000	Number of police officers per 100 000 population
	Personal safety	Likert scale	Level of safeness felt
	Cybersecurity	Likert scale	The level of cybersecurity of the cities' systems
	Data privacy	Likert scale	The level of data protection by the city
Mobility	Use of electrical cars	% of people	Share of population using electrical cars
	Access to public transport	% of people	Share of population with access to a public transport stop within 500m
	Public transport trips	#/year	Annual number of public transport trips per capita
	Personal automobiles	#/capita	Number of personal automobiles per capita
	International accessibility	% of people	Share of population with access to international transport
	Access to vehicle sharing solutions for city travel	#/100.000	Number of vehicles available for sharing per 100.000 inhabitants
	Length of the bike route network	% in km	% of bicycle paths and lanes in relation to the length of streets (excluding motorways)

Table 3 – *Identification of the KPIs that constitute the Sub Dimensions "Health", "Safety" and "Mobility" which make part of the "People" Dimension.*

Access to other services	Access to public amenities	% of people	Share of population with access to at least one type of public amenity within 500m
	Access to commercial amenities	% of people	Share of population with access to at least six types of commercial amenities providing goods in 500 m
	Access to cultural facilities	% of people	Cinema/museum/theater attendance per inhabitant
	Access to high speed internet	#/100	Fixed (wired)-broadband subscriptions per 100 inhabitants
	Access to public free WiFi	% of m2	Public space Wi-Fi coverage
Education	Access to educational resources	Likert scale	The extent to which the city provides easy access (either physically or digitally) to a wide coverage of educational resources
	Open-mindedness	Likert scale	Immigration-friendly environment (attitude towards immigration)
	Digital literacy	% of people	Percentage of target group reached
Quality of housing and the built environment	Diversity of housing types	Simpson Diversity Index	Simpson Diversity Index of total housing stock in the citystock in the area
	Preservation of cultural heritage	Likert scale	The extent to which preservation of cultural heritage of the city is considered in urban planning
	Green space	hectares/ 100.000 population	Green area

Table 4 – *Identification of the KPIs that constitute the Sub Dimensions "Access to other Services", "Education" and "Quality of housing and the built environment" which make part of the "People" Dimension.*

2) Planet

Sub Dimension	KPI Title	Measurement Unit	Definition
Energy and mitigation	Energy consumption/demand (annual final energy consumption)	MWh/cap/yr	Annual final energy consumption for all uses and forms of energy
	Renewable energy production (generated within the city)	% of MWh	The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption
	CO2 emissions	t CO2/cap/yr	CO2 emissions in tonnes per capita per year
	Local freight transport fuel mix	% in kms	The ratio of renewable fuels in the local freight transport fuel mix
Materials water and land	Domestic material consumption	t/cap/year	The total amount of material directly used in the city per capita
	Potable water	% of population	Percentage of population with potable water supply service
	Water consumption	liters/cap/year	Total Water consumption per capita per day
	Grey and rain water reuse	% of houses	Percentage of houses equipped to reuse grey and rain water
	Water exploitation index	% of m3	Annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water
	Water losses	% of m3	Percentage of water loss of the total water consumption
	Population density	#/km2	Number of people per km2
	Local food production	% of tonnes	Share of food consumption produced within a radius of 100 km
Climate resilience	Climate resilience strategy	Likert scale	The extent to which the city has developed and implemented a climate resilient strategy
	Urban heat	°C	Maximum difference in air temperature within the city compared to the countryside during the summer months

Table 5 – *Identification of the KPIs that constitute the Sub Dimensions "Energy and Mitigation", "Materials, water and land" and "Climate Resilience" which make part of the "Planet" Dimension.*

Pollution and waste	Nitrogen oxide emissions (NOx)	g/cap	Annual nitrogen oxide emissions (NO and NO2) per capita
	Particulate matter emissions (PM2,5)	g/cap	Annual particulate matter emissions (PM 2,5) per capita
	Respiratory diseases	% of people	Percentage of fatal chronic lower respiratory diseases
	Air quality index	Index	Annual concentration of relevant air pollutants
	Noise pollution	% of people	Share of the population affected by noise >55 dB(a) at night time
	Municipal solid waste	t/cap/yr	The amount of municipal solid waste generated per capita annually
	Recycling rate	% of tonnes	Percentage of city's solid waste that is recycled
Ecosystem	Share of green and water spaces	% in km2	Share of green and water surface area as percentage of total land area
	Native species	% of species	Percentage change in number of native species
	Increased ecosystem quality and biodiversity	Likert scale	The extent to which ecosystem quality and biodiversity aspects have been taken into account

Table 6 – *Identification of the KPIs that constitute the Sub Dimension "Pollution and Waste" and "Ecosystem" which make part of the "Planet" Dimension.*

3) Prosperity

Sub Dimension	KPI Title	Measurement Unit	Definition
Employment	Uneployment rate	% of people	Percentage of the labour force unemployed
	Youth unemployment rate	% of people	Percentage of youth labour force unemployed
Equity	Fuel poverty	% of households	The percentage of households unable to afford the most basic levels of energy
	Poverty rate	% of people	The percentage of homeless people leaving in the city
	Affordability of housing	% of people	% of population living in affordable housing

Table 7 – *Identification of the KPIs that constitute the Sub Dimensions "Employment" and "Equity" which make part of the "Prosperity" Dimension.*

Green economy	Share of certified companies	% of companies	Share of companies based in the city holding an ISO 14001 certificate
	Share of green public Procurement	% in Millions of €	Percentage annual procurement using environmental criteria as share of total annual procurement of the city administration
	Green jobs	% of jobs	Share of jobs related to environmental service activities that contribute substantially to preserving or restoring environmental quality
	Freight movement	# of movements	Freight movement is defined as the number of freight vehicles moving into an area (e.g. the city)
Economic performance	Gross domestic product	€/cap	City's gross domestic product per capita
	Debt service ratio	% of total revenues	Debt service expenditure as a % of a municipality's own-source revenue
	New business registered	#/100.000	Number of new businesses per 100,000 population
	International embeddedness	% of companies	Percentage of companies with headquartered in the city quoted on national stock market
Innovation	Creative industry	% of people	Share of people working in creative industries
	Innovation hubs in the city	#/100.000	Number of innovation hubs in the city, whether private or public, per 100.000 inhabitants
	Accessibility of open data sets	# stars	The extent to which the open city data are easy to use
	Research intensity	% in euros	R&D expenditure as percentage of city's GDP
	Patent applications	#/100.000	Number of registered patent applications per inhabitant
	Open data	#/100.000	# of open government datasets per 100.000 inhabitants

Table 8 – *Identification of the KPIs that constitute the Sub Dimensions "Green economy", "Economic performance" and "Innovation" which make part of the "Prosperity" Dimension.*

Attractiveness & competitiveness	Congestion	% in hours	Increase in overall travel times when compared to free flow situation (uncongested situation)
	Public transport use	#/cap/year	Annual number of public transport trips per capita
	Net migration	#/1000	Rate of population change due to migration per 1000 inhabitants
	Population dependency ratio	#/100	Number of economically dependent persons (net consumers) per 100 economically active persons (net producers)
	Tourism intensity	#nights/100k	Number of tourist nights per year per 100.000 inhabitants

Table 9 – *Identification of the KPIs that constitute the Sub Dimension "Attractiveness & competitiveness" which makes part of the "Prosperity" Dimension.*

4) Governance

Sub Dimension	KPI Title	Measurement Unit	Definition
Organisation	Transparent governance	Likert scale	Satisfaction with transparency of bureaucracy and with fight against corruption
	Cross-departmental integration	Likert scale	The extent to which administrative departments contribute to "smart city" initiatives and management
	Establishment within the administration	Likert scale	The extent to which the smart city strategy has been assigned to one department/director and staff resources have been allocated
	Monitoring and evaluation	Likert scale	The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported
	Availability of government data	Likert scale	The extent to which government information is published
	Female participation in decision-making	% of female representatives	Share of female city representatives
Community involvement	Open public participation	#/100.000	Number of public participation processes per 100.000 per year
	Voter participation	% of people	% of people that voted in the last municipal election as share of total population eligible to vote

Table 10 – *Identification of the KPIs that constitute the Sub Dimensions "Organisation" and "Community involvement" which make part of the "Governance" Dimension.*

Multi-level governance	Smart city policy	Likert scale	The extent to which the city has a supportive smart city policy
	Expenditures by the municipality for a transition towards a smart city	€/capita	Annual expenditures by the municipality for a transition towards a smart city
	Multilevel government	Likert	The extent to which the city cooperates with other authorities from different levels

Table 11 – *Identification of the KPIs that constitute the Sub Dimension "Multi-level governance" which makes part of the "Governance" Dimension*

Step 2 – KPIs addition

After analysing the Dimensions, Sub dimensions and KPIs of other studies, the author has documented that there it was a lack of KPIs defending the citizens' best interests, so he propose (together with his team at Ubiwhere, in a moment of brainstorming) the addition of a few more KPIs that were worthy to be considered in the final equation. The idea that the KPIs which are already been considering by reference entities are not considering the entire picture was in the base of the motivation to write this work.

Dimension	Sub Dimension	KPI Title	Measurement Unit	Definition
People	**Health**	Satisfaction with health care service	Likert scale	The level of satisfaction about the health care service given in the city
	Mobility	Satisfaction with the public transports	Likert scale	Level of satisfaction felt with the conditions of the public transportation
	Access to other services	Satisfaction with mobile operators	Likert scale	Level of satisfaction for the quality of the services provided by the mobile operators
		Satisfaction with Wi-Fi network	Likert scale	Level of satisfaction with the Wi-Fi signal in the region
	Education	Satisfaction with education policies and conditions	Likert scale	Level of satisfaction with the teaching mode and the facilities conditions provided by the city

Table 12 – *Author's KPIs added to the "People" Dimension.*

Dimension	Sub Dimension	KPI Title	Measurement Unit	Definition
Planet	**Energy and Mitigation**	Satisfaction with energy providers	Likert scale	Level of satisfaction with the service provided by energy providers and distributors

Table 13 – *Author's KPIs added to the "Planet" Dimension.*

Dimension	Sub Dimension	KPI Title	Measurement Unit	Definition
Prosperity	**Equity**	Economic power	Likert scale	Capability to don't just afford basic needs
		Gender equity	Likert scale	Level of gender equity felt

Table 14 – *Author's KPIs added to the "Prosperity" Dimension.Step 3 – Citizens inquiry about the importance of each KPI*

Step 3 – Inquiry

This is the most important step of the "Methodology", because it is here that this study starts to differentiate from those already made. After the collection and analysis of the KPIs from the reference entities, in this step it is detailed how the inquiry was constituted and what were the main objectives which took the author to question citizens about the theme. The answers collected were used to understand in citizens' opinion about the Smart Cities concept and what are the most important KPIs and Sub Dimensions for the evaluation of what the Smart City index should consider.

First of all the inquiry was sent by email to all the contacts related to Smart Cities the author has met at his work, secondly it was published a post in his LinkedIn to all his connections. This strategy was made to try to have the most number of answers from citizens who are somehow related with the smart cities theme.

The inquiry is divided in three parts:

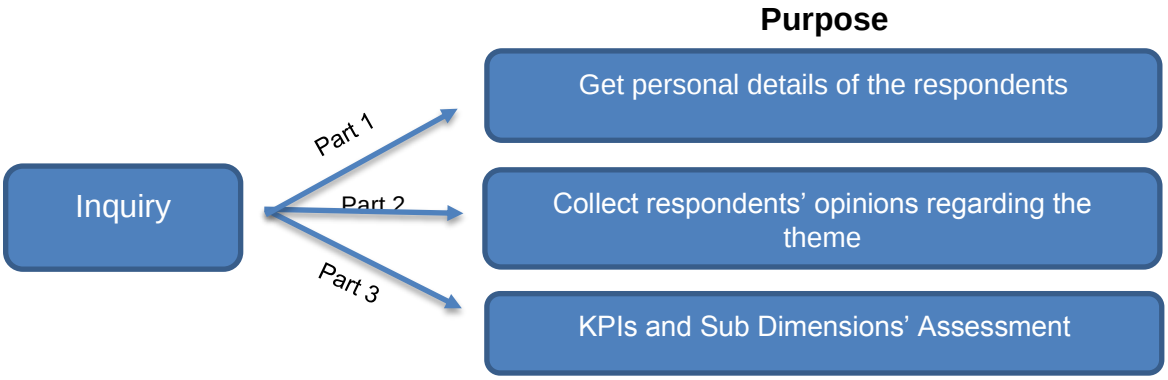

Fig. 19 – *Purposes of each one of the three parts that constitute the inquiry.*

1. First, was asked questions regarding personal details of the respondents to later relate the answer with their age, gender, the city they live and their nationality/culture of each one. Is was also asked if the respondent works with the theme in its daily life to understand how much is he into the subject.

   Due to the fact that this is an inquiry which is asking personal opinions it will be important to take into consideration the historical/cultural “background” of each respondent.

2. One “Closed” question to perceive if in the opinion of each respondent the implemented technology defines a certain city as a Smart City. This will show if the Smart City expression is related to the deployment of new and disruptive technology.

   Two “Open” questions, first about the respondent’s opinion of what a Smart City is to understand what is the line that separates a city from a Smart City and if there is a common definition (or parts of it), a pattern in the different answers, and then what was the smartest solution the city where each respondent live has adopted to see if the answers are related to technological or non-technological solutions.

3. Assessment of the several KPIs through a Likert Scale (from 1 - non important to 5 – very important) to prioritize and evaluate the citizens’ given level of importance of each KPI and their sub dimensions.

   The clear objective here is to understand from the citizens’ point of view what should be the value/coefficient of each KPI in the final equation of the Smart City index/level. With the information of the inquiries it will be possible to establish an average importance value to each KPI and Sub dimension which will determine the multiplied coefficient in the final equation.

4. Results and Discussions

Step 4 – Analysis of the obtained data and revision of the KPIs

Having the answers to the inquiry, it is time to analyse them and understand first if there is any KPI which deserves to be added to the list and then define what is the coefficient that must be aggregated to each KPI and Sub Dimension in the final equation according to the opinions of the respondents.

To the present inquiry, it were obtained **57 answers**. As it was mentioned on Step 3, the following numeration will be according to the type of question it refers.

Part 1: Personal Details

The nationality of the respondents is divided for three countries: Portugal (94.6%), Spain (3.6%) and France (1.8%).

	Answer	Percentage	Number of Respondents
Áge	18 - 25	14%	8
	26 - 40	38,6%	22
	41 - 60	43,9%	25
	+ 60	3,5%	2
Gender	Male	43,9%	25
	Female	56,1%	32

Table 15 – *Results of the inquiry to the Age and Gender questions.*

According to the results, the cities where the respondents live in are:

City	Number of Respondents	Percentage
Águeda	1	1,75%
Álcochete	1	1,75%
Amadora	1	1,75%
Aveiro	10	17,5%
Barcelona	1	1,75%
Braga	1	1,75%
Cantanhede	2	3,5%

Cascais	1	1,75%
Coimbra	9	15,7%
Condeixa	1	1,75%
Coruche	1	1,75%
Esposende	1	1,75%
Faro	1	1,75%
Figueira da Foz	1	1,75%
Ghent	1	1,75%
Lisbon	6	10,6%
Madrid	1	1,75%
Marinha Grande	1	1,75%
Mealhada	3	5,45%
Oeiras	1	1,75%
Ponta Delgada	1	1,75%
Porto	2	3,55%
Samora Correia	2	3,55%
Santa Maria da Feira	2	3,55%
Vila Nova de Famalicão	2	3,55%
Vale de Cambra	1	1,75%
Vila Nova de Gaia	1	1,75%
Viseu	1	1,75%

Table 16 – *Answers to the question about the city each respondent lives in.*

To the question "**Is your current job (or one of your jobs was) related to the Smart Cities theme**?" – 40% of respondents have responded positively.

Part 2: Questions about the Smart Cities theme

To the question "**Does the implemented technology in a city defines it as a Smart City?**", the results were very tight, with 54,4% of the respondents answering positively.

To the open question "**What does Smart City stand for you?**", it has to be underlined the fact that in 57 answers there are 42,1% which refers the word efficiency or sustainability and 36,8% the idea of improvement of citizen's quality of life.

Some of the answers collected were[7]:

- "A city which has its policies and management strategies determined and properly sustained by quality indicators" Alexandra Roeger, Vice President of the Municipality of Esposende;
- "A city that facilitates my life, promoting my well-being and happiness. Providing a balance between citizen's duty and the benefit of living there" João Costa, Administrator of FAGAR (Water and Waste Faro's Municipal Entity);
- "Innovation in every corner, plus real-time knowledge of city important data (energy, parking, people, etc.)" Pedro Cruz, Business Development Manager of Controlar Lda;
- "An inclusive and cohesive territory that optimizes the use of environmentally, socially and economically managed resources in a participatory manner, based on open and integrated governance, collaboration among all stakeholders and transparent and networked communication and information" Rosário Daugbjerg, Municipality of Cascais;
- "A city that listens to those who inhabit it and uses all available tools (technological, political) to improve the lives of citizens" Rafael Cubiles, Business Development Manager of Sensefields;
- "Smooth information processes and the digitisation of the City itself" André Duarte, Software Developer of Ubiwhere;
- "Reversible lane, in a tight and with huge demand of traffic, using traffic lights and an appropriate schedule." Miguel Velosa Rodrigues, City Account Manager of Siemens;
- "A liveable city, with quality of life. That means equality of opportunities for all citizens, security, good access, green areas, and transparency in governance" Natália Silva, Project Manager of FRCT;
- "Usage of ICT to improve different aspect of the citizen´s/tourist/investor customer experience related to services offered by the city. Ultimately improving quality of life" Ruben Riestra, Innovation Management Unit – Director of Inmark Europa SA;
- "New approaches for cities beyond the current state of the art that improve the citizens' quality of life and bring new perspectives on sustainability and environmental issues" Eunice Ribeiro, EU Programmes Manager of Ubiwhere;
- Taking into account that the most part of the respondents live in Portugal, the following answers are about the cities of this country. Thus, to the open question

[7] Only the respondents who have filled their personal data in the inquiry and agreed to be quoted are referred in the document.

"What was the smartest solution your city has adopted?" it were mentioned: Public Lighting Management (2 answers);Water Quality Management (2 answers);Tourism Applications (1 answer); Online Services (1 answer); Bike Sharing (2 answer); Car Sharing and Ride-Hailing (1 answer); Waste Management (1 answer); Traffic Light Management (2 answer); "Pavnext" – which is a solution capable of reduce vehicle's speed without any driver action (1 answer); Electrical Public Transportation (2 answer); and Green and Pedestrian Areas (1 answer);

The respondent who is living in Barcelona, said "decidim.Barcelona" which is a participatory portal where citizens can tell the city what they would like to see implemented.

It is also important to underline the fact that more than 20% of the respondents have answered that their cities have not implemented any Smart Solution until this moment.

Part 3: Respondents Assessment about KPIs and their Dimensions

After these primarily questions, came the most important part of the inquiry to be filled by the respondents. They were challenged to give their opinion, this means evaluating in a Likert scale from 1 to 5 the level of importance they think each Key Performance Indicator of the different Sub dimensions deserves, to ultimately, according to the average of the results calculate what is the value of the coefficient that should come aggregated (before) of each KPI in the final equation to calculate the Smart City Index of a certain city. The coefficient of each Sub dimension will be also calculated. The graphics with the responses are in Annex 2.

i. KPIs Assessment

1) People

a. Health

Although the results were very tight, as we can see in Table 17, for the respondents, the importance given to the "Level of satisfaction with health care service" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Health" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Access to basic health care	1	4	7	16	29	**4,19**
Level of satisfaction with health care service	0	0	5	22	30	**4,44**
Encouraging a healthy lifestyle	0	3	8	20	26	**4,21**
Life Expectancy	0	1	10	22	24	**4,21**
Hospital beds	0	3	12	18	24	**4,11**

Table 17 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Health" which makes part of the "People" Dimension.*

b) Safety

In Table 18, it is possible to see that the importance given to the "Crime Rate" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Safety" Sub Dimension. At the same time, the lower value goes to the "Police Officers".

KPI Title	1	2	3	4	5	Coefficient
Traffic accidents	0	3	10	20	24	**4,14**
Crime Rate	0	3	7	16	31	**4,32**
Police officers	1	6	23	15	12	**3,54**
Personal safety	0	0	13	17	27	**4,25**
Cybersecurity	1	5	13	17	21	**3,91**
Data privacy	0	3	12	18	24	**4,11**

Table 18 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Safety" which makes part of the "People" Dimension.*

c) Mobility

In Table 19, it is possible to see that the importance given to the "Access to public transport" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Mobility" Sub Dimension. At the same time, the lower value goes to the "Personal Automobiles".

KPI Title	1	2	3	4	5	Coefficient
Use of electrical cars	4	4	17	19	13	**3,58**
Access to public transport	1	3	6	18	29	**4,25**
Public transport trips	3	4	12	23	15	**3,75**
Personal automobiles	3	10	17	20	7	**3,32**
Level of satisfaction felt with the conditions of the public transports	2	2	8	20	25	**4,12**
International accessibility	2	2	21	19	13	**3,68**
Access to vehicle sharing solutions for city travel	1	9	14	19	14	**3,63**
Length of the bike route network	3	5	8	23	18	**3,84**

Table 19 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Mobility" which makes part of the "People" Dimension.*

d) Access to other services

In Table 20, it is possible to see that the importance given to the "Access to high speed internet" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Access to other services" Sub Dimension. At the same time, the lower value goes to the "Access to commercial amenities".

KPI Title	1	2	3	4	5	Coefficient
Access to public amenities	0	2	22	23	10	**3,72**
Access to commercial amenities	1	3	26	20	7	**3,51**
Access to cultural facilities	1	4	11	21	20	**3,96**
Access to high speed internet	0	2	8	21	26	**4,25**
Satisfaction with mobile operators	0	2	8	27	20	**4,14**
Satisfaction with WiFi network	0	2	12	18	25	**4,16**
Access to public free WiFi	0	4	13	18	22	**4,02**

Table 20 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Access to other services" which makes part of the "People" Dimension.*

e) Education

In Table 21, it is possible to see that the importance given to the "Access to educational resources" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Education" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Access to educational resources	0	1	3	16	37	**4,56**
Satisfaction with education policies and conditions	0	1	5	20	31	**4,42**
Open-mindedness	2	1	11	23	20	**4,02**
Digital Literacy	0	2	8	21	26	**4,25**

Table 21 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Education" which makes part of the "People" Dimension.*

f) Quality of housing and the built environment

In Table 22, it is possible to see that the importance given to the "Green space" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Quality of housing and the built environment" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Diversity of housing types	0	7	16	25	9	**3,63**
Preservation of cultural heritage	1	2	10	23	21	**4,07**
Green space	0	1	5	15	36	**4,51**

Table 22 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Quality of housing and the built environment" which makes part of the "People" Dimension.*

2) Planet

a) Energy and mitigation

In Table 23, it is possible to see that the importance given to the "CO2 emissions" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Energy and mitigation" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Energy consumption/demand	1	4	6	27	19	**4,04**
Satisfaction with the service provided by energy providers and distributors	0	1	11	23	22	**4,16**
Renewable energy production	1	2	7	16	31	**4,30**
CO2 emissions	2	2	4	16	33	**4,33**
Local freight transport fuel mix	1	2	12	22	20	**4,02**

Table 23 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Energy and mitigation" which makes part of the "Planet" Dimension.*

b) Materials, water and land

In Table 24, it is possible to see that the importance given to the "Potable water" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Materials, water and land" Sub Dimension. At the same time, the lower value goes to the "Population density".

KPI Title	1	2	3	4	5	Coefficient
Domestic material consumption	2	4	9	24	18	**3,91**
Potable water	1	1	5	15	35	**4,44**
Water consumption	2	4	11	17	23	**3,96**
Grey and rain water reuse	2	5	9	22	19	**3,89**
Water exploitation index	1	4	14	17	21	**3,93**
Water losses	1	2	9	15	30	**4,25**
Population density	1	4	20	14	18	**3,77**
Local food production	4	3	10	19	21	**3,88**

Table 24 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Materials, water and land" which makes part of the "Planet" Dimension.*

c) Climate resilience

In Table 25, it is possible to see that the importance given to the two KPIs that constitute the "Climate resilience" Sub Dimension have similar values to be considered in the final equation of the Smart City index.

KPI Title	1	2	3	4	5	Coefficient
Climate resilience strategy	2	3	11	20	21	**3,96**
Urban heat	1	5	11	23	17	**3,88**

Table 25 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Climate resilience" which makes part of the "Planet" Dimension.*

d) Pollution and waste

In Table 26, it is possible to see that the importance given to the "Respiratory diseases" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Pollution and waste" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Nitrogen oxide emissions	1	6	4	19	27	**4,14**
Particulate matter emissions	1	5	6	17	28	**4,16**
Respiratory diseases	1	4	6	17	29	**4,21**
Air quality index	2	5	6	20	24	**4,04**
Noise pollution	2	3	10	17	25	**4,05**
Municipal solid waste	2	5	6	20	24	**4,04**
Recycling rate	2	1	4	15	35	**4,40**

Table 26 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Pollution and waste" which makes part of the "Planet" Dimension.*

e) Ecosystem

In Table 27, it is possible to see that the importance given to the "Share of green and water spaces" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Ecosystem" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Share of green and water spaces	0	3	14	17	23	**4,05**
Native species	1	4	17	17	18	**3,82**
Increased ecosystem quality and biodiversity	1	4	17	16	19	**3,84**

Table 27 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Ecosystem" which makes part of the "Planet" Dimension.*

3) Prosperity

a) Employment

In Table 28, it is possible to see that the importance given to the two KPIs that constitute the "Employment" Sub Dimension have similar values to be considered in the final equation of the Smart City index.

KPI Title	1	2	3	4	5	Coefficient
Unemployment rate	2	1	9	17	28	**4,19**
Youth unemployment rate	3	0	9	14	31	**4,23**

Table 28 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Employment" which makes part of the "Prosperity" Dimension.*

b) Equity

In Table 29, it is possible to see that the importance given to the "Fuel poverty" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Equity" Sub Dimension. At the same time, the lower value goes to the "Gender equity".

KPI Title	1	2	3	4	5	Coefficient
Fuel poverty	1	3	10	25	28	**4,86**
Economic power	1	5	6	18	27	**4,14**
Gender equity	2	2	13	20	20	**3,95**
Poverty rate	0	3	10	17	27	**4,19**
Affordability of housing	0	2	15	16	24	**4,09**

Table 29 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Equity" which makes part of the "Prosperity" Dimension.*

c) Green economy

In Table 30, it is possible to see that the importance given to the four KPIs that constitute the "Green economy" Sub Dimension have similar values to be considered in the final equation of the Smart City index.

KPI Title	1	2	3	4	5	Coefficient
Share of certified companies	3	3	17	19	15	**3,70**
Share of green public procurement	3	1	15	22	16	**3,82**
Green jobs	1	7	13	22	14	**3,72**
Freight movement	1	4	16	24	12	**3,74**

Table 30 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Green economy" which makes part of the "Prosperity" Dimension.*

d) Economic performance

In Table 31, it is possible to see that the importance given to the four KPIs that constitute the "Economic performance" Sub Dimension have similar values to be considered in the final equation of the Smart City index.

KPI Title	1	2	3	4	5	Coefficient
Gross domestic product	2	3	14	20	18	**3,86**
Debt service ratio	3	3	18	19	14	**3,67**
New Business registered	2	3	14	22	16	**3,82**
International embeddedness	3	4	16	21	13	**3,65**

Table 31 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Economy performance" which makes part of the "Prosperity" Dimension.*

e) Innovation

In Table 32, it is possible to see that the importance given to the "Accessibility of open data sets" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Innovation" Sub Dimension. At the same time, the lower value goes to the "Patent applications".

KPI Title	1	2	3	4	5	Coefficient
Creative industry	3	0	11	23	20	**4,00**
Innovation hubs	3	2	13	23	16	**3,82**
Accessibility of open data sets	2	3	11	16	25	**4,04**
Research intensity	2	2	18	19	16	**3,79**
Patent applications	5	7	22	12	11	**3,30**
Open data	2	5	19	11	20	**3,74**

Table 32 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Innovation" which makes part of the "Prosperity" Dimension.*

f) Attractiveness and competitiveness

In Table 33, it is possible to see that the importance given to the "Congestion" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Attractiveness and competitiveness" Sub Dimension. At the same time, the lower value goes to the "Net migration".

KPI Title	1	2	3	4	5	Coefficient
Congestion	0	2	10	24	21	**4,12**
Public transport use	1	3	8	23	22	**4,09**
Net migration	1	5	18	20	13	**3,68**
Population dependency ratio	1	4	13	24	15	**3,84**
Tourism intensity	1	1	23	18	14	**3,75**

Table 33 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Attractiveness and competitiveness" which makes part of the "Prosperity" Dimension.*

4) Governance

a) Organisation

In Table 34, it is possible to see that the importance given to the "Transparent governance" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Organisation" Sub Dimension. At the same time, the lower value goes to the "Female participation in decision-making".

KPI Title	1	2	3	4	5	Coefficient
Transparent governance	1	3	7	15	31	**4,26**
Cross-departmental integration	1	1	12	14	29	**4,21**
Establishment within the administration	0	3	16	17	21	**3,98**
Monitoring and evaluation	0	1	17	12	27	**4,14**
Availability of government data	0	4	10	15	28	**4,18**
Female participation in decision-making	1	8	11	16	21	**3,84**

Table 34 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Organisation" which makes part of the "Governance" Dimension.*

b) Community involvement

In Table 35, it is possible to see that the importance given to the "Voter participation" in the final equation to define the Smart City index of a city is the one which has the biggest value in the "Community involvement" Sub Dimension.

KPI Title	1	2	3	4	5	Coefficient
Open public participation	2	1	19	20	15	**3,79**
Voter participation	2	1	12	19	23	**4,05**

Table 35 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Community involvement" which makes part of the "Governance" Dimension.*

c) Multi-level governance

In Table 36, it is possible to see that the importance given to the two KPIs that constitute the "Multi-level governance" Sub Dimension have similar values to be considered in the final equation of the Smart City index.

KPI Title	1	2	3	4	5	Coefficient
Smart city policy	1	3	12	21	20	**3,98**
Expenditures by the municipality for a transition towards a smart city	1	1	15	23	17	**3,95**
Multilevel government	1	2	14	22	18	**3,95**

Table 36 – *Respondents' assessment of the KPIs that constitute the Sub Dimension "Multi-level governance" which makes part of the "Governance" Dimension.*

ii. Sub Dimensions Assessment

For the coefficient of each sub dimension, it were collected the following results:

1) People

For the “People” dimension, as we can see in Table 37 and in Figure 20, the most important Sub Dimension for the respondents is “Health”.

Sub Dimension	1	2	3	4	5	Coefficient
Health	0	2	1	10	44	**4,68**
Safety	0	1	3	18	35	**4,53**
Mobility	0	0	6	23	28	**4,39**
Access to other services	0	0	12	29	16	**4,07**
Education	0	0	2	13	42	**4,70**
Quality of housing and the built environment	0	1	4	33	19	**4,23**

Table 37 – *Respondents’ assessment of the Sub Dimensions that constitute the “People” Dimension.*

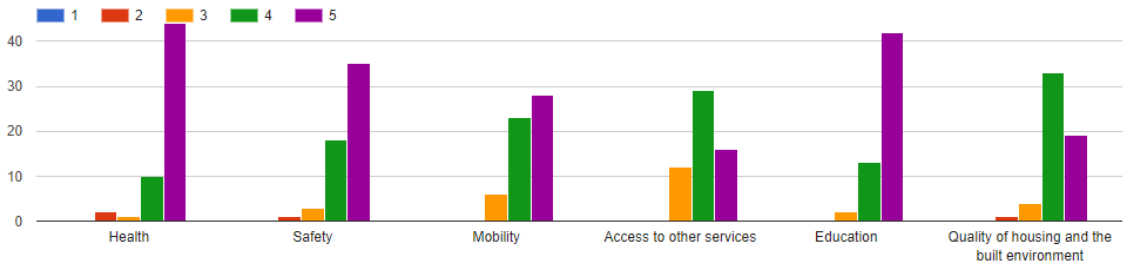

Fig. 20 – *Graphical distribution of the assessment made to the Sub Dimensions that constitute the “People” Dimension.*

2) Planet

For the “Planet” dimension, as we can see in Table 38 and in Figure 21, the most important Sub Dimension for the respondents is “Pollution and waste”.

Sub Dimension	1	2	3	4	5	Coefficient
Energy and mitigation	0	4	4	18	31	**4,33**
Materials, water and land	0	4	4	19	30	**4,32**
Climate resilience	0	4	6	20	27	**4,23**
Pollution and waste	1	4	2	11	39	**4,46**
Ecosystem	0	3	8	14	32	**4,32**

Table 38 – *Respondents’ assessment of the Sub Dimensions that constitute the “Planet” Dimension.*

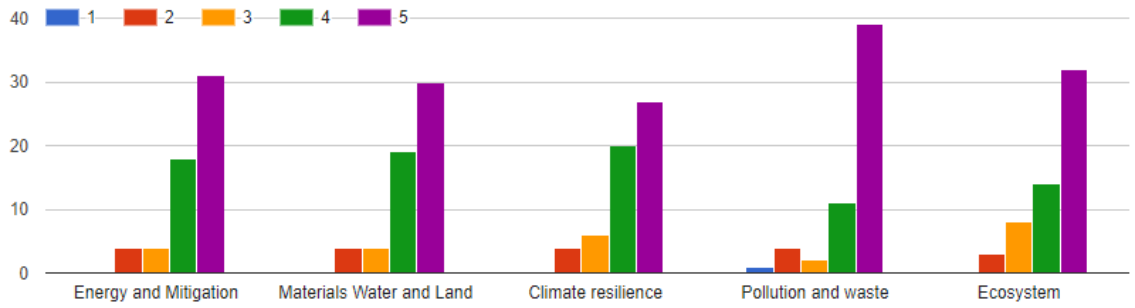

Fig. 21 – *Graphical distribution of the assessment made to the Sub Dimensions that constitute the “Planet” Dimension.*

3) Prosperity

For the “Prosperity” dimension, as we can see in Table 39 and in Figure 22, the most important Sub Dimension for the respondents is “Employment”.

Sub Dimension	1	2	3	4	5	Coefficient
Employment	1	0	2	21	33	**4,49**
Equity	0	0	8	19	30	**4,39**
Green economy	1	2	8	22	24	**4,16**
Innovation	0	1	5	20	31	**4,42**
Attractiveness and competitiveness	0	2	7	24	24	**4,23**

Table 39 – *Respondents’ assessment of the Sub Dimensions that constitute the “Prosperity” Dimension.*

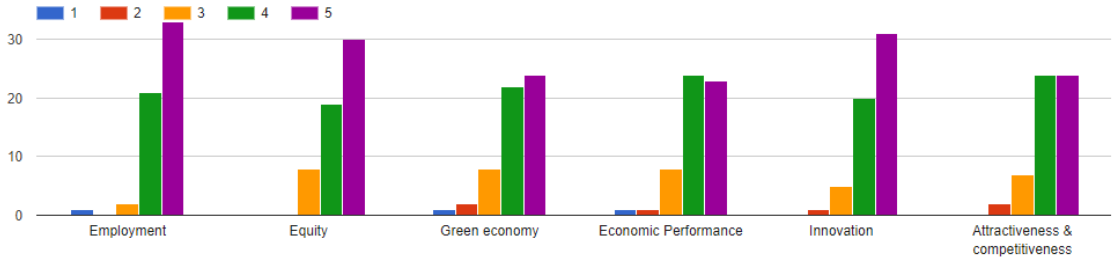

Fig. 22 – *Graphical distribution of the assessment made to the Sub Dimensions that constitute the “Prosperity” Dimension.*

4) Governance

For the “Governance” dimension, as we can see in Table 40 and in Figure 23, the most important Sub Dimension for the respondents is “Organisation”.

Sub Dimension	1	2	3	4	5	Coefficient
Organisation	0	0	9	16	32	**4,40**
Community Involvement	0	1	9	15	32	**4,37**
Multi-level governance	0	1	10	21	25	**4,23**

Table 40 – *Respondents’ assessment of the Sub Dimensions that constitute the “Governance” Dimension.*

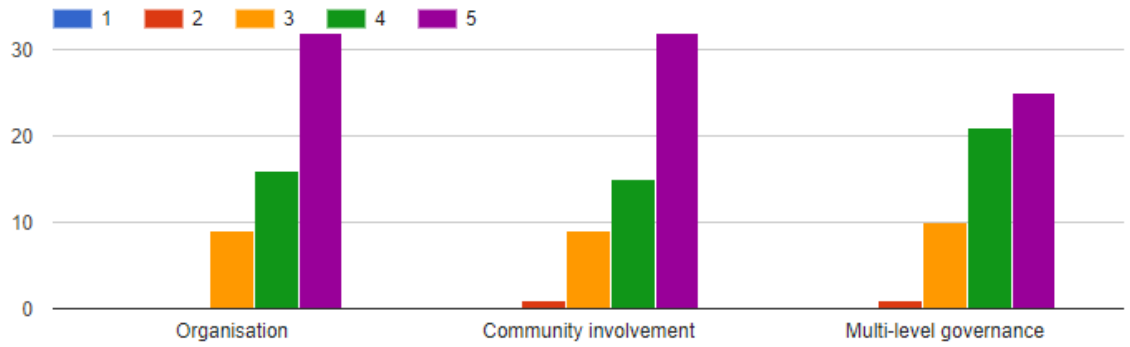

Fig. 23 – *Graphical distribution of the assessment made to the Sub Dimensions that constitute the “Governance” Dimension.*

Step 5 – Definition of the Smart City Index equation

Finally, with all the gathered and analysed data is time to define each coefficient and how looks like the final equation, which can be used to every city evaluate its current Smartness level and understand what should be the priorities to overcome the main purpose: citizens' happiness and quality of life.
The final equation can be written as:

I. $DimensionLEVEL = \sum_{i=1}^{n} \sum_{j=1}^{m} Sub\ Dimension\ Coefficient\ i * (Assessment\ of\ the\ KPI\ j * KPI\ Coefficient)j$

   a. "n" is the number of Sub Dimensions in each Dimension;
   b. "m" is the number of KPIs in each Sub Dimension;

II. $SmartCityLEVEL = \sum_{k=1}^{4} DimensionLevel$

Sharing a similar vision, Félix Priano and Cristiana Guerra from the University of Madrid, claimed that "the score for each city that reflect the smart level in each of the problems must not only take into account the assessment of the indicators but also the scope of the solution implemented and the assessment of the people" (Priano, F. H., & Guerra, C. F., 2014).

*Smart City LEVEL Problem i = Assessment of the indicators * Scope of the solution implemented *Assessment of the People*

This resulted in a score for each city's smart level:

$$SmartCityLEVEL = \sum_{i=1}^{n} (SmartCityLEVEL_{Problemi})$$

Step 6 - The Barriers and the process of becoming a Smart City

Almost one hundred people have joined the Working Group at the Smart Towns 2017 conference in Ljubljana to understand what are the barriers and challenges that cities/companies have to overcome as well as to have the opinion from the audience about what is the process for any city become a Smart City and if it is possible or not.

The term “Smart City” can be applied to other ecosystems like a village, an enterprise or even a house. It is not mandatory to take a City as the case study.

It was behalf this thinking that in the last days of November of 2017 several experts from EU cities and commissioners have joined in Ljubljana, Slovenia, at the “Smart Towns Conference” and where the author (Figure 24) was present to conduct a working group with the guests of the conference to discuss the main challenges and barriers that every city, town, village has to overcome in this journey.

Fig. 24 - *The author presenting the objectives of the working group.*

“Even if a city declares that it aspires to be a smart city that will not suffice in terms of internal leadership to establish that aspiration. For a start, political willingness and long-term commitment are needed to put and keep things in motion. Secondly, smart city leadership has to find a place in the city administration too. A team or even a separate department has to claim the leadership in order to consolidate smart city projects, incite city departments to participate, and form a point of contact for ecosystem players.” – (Van Den Bergh and Viaene 2015)

As it was also already described in the present document, from the cities and governments perspective it is really important to have open platforms where the information collected is open and accessible for developers and researcher in order to build solutions on top of it preventing vendor lock-in.

The Minister of Public Administration of the Republic of Slovenia said: “open data is the ground for new ideas and solutions”.

To address the importance of deploying Smart City solutions, an European Comissions’ Senior Advisor have mentioned that “in 2030, 80% of people will live in cities”;”80% of the energy produced is consumed in the cities” and “80% of the Greenhouse Gases emitted are produced in the cities”.

Although most part of the participants have agreed that the main barrier to a city adopt a Smart City strategy is the mentality and thinking of the city mayor, below is mentioned the different barriers and challenges discussed.

Challenges and Barriers:

- Mindset of City Administration – the future of the cities depends on the mindset of their decision makers, if the mayor does not have the willing to improve cities processes the probably of defining and starting a Smart City initiative is greatly reduced;
- Lack of resources, human resources’ capacities and skills;
- Gap between projects result and previews expectations – because a certain technology had success in other city does not mean it will necessarily be successful in every city (expectations must be connected with the pilot’s dimension and characteristics);
- Too many solutions and providers – because of the amount of different solutions in the market it is difficult for City Administrations not only prioritize them according to the areas they want to focus but also understand which are the best solutions to invest;
- Transversality of the person responsible for the department of smart cities - he has to go through the Environmental department, mobility, etc...
- Culture/Religion – it is necessary to be aware of what citizens think it is correct and understand the level of intrusiveness until that they accept the deployment of that technology (this is even a bigger barrier in the not EU countries);
- The difficulty of the small corporations in commercializing their products – even if they have the best technology in the market it is difficult to be preferable than the

ones from major brands and also break the relationships already existed within the ecosystem:

- Integration and standardization – the complementary of the different services/solutions and verticals;
- Political/Business Relationships – the ecosystems created sometimes do not permit an evolution in the cities;
- Gaps between stakeholders – it is important to reduce the distance between citizens, city administration and solution providers in order to have a better result on the deployed technology (that happens when the majority agrees with the new implementation);
- Resistance to change – especially when we are talking about people who does the same activity with the same processes “for centuries”;
- Funding – although there is a lot of opportunities within EU to get funds from the Commission Programmes, it is not that easy to obtain funds;
- Scale – even with funds it is difficult to scale the different implementations. Projects tend to be pilots or small deployments;
- Legislation – sometimes everything is aligned to deploy a new technology and at the last minute it is verified that the legislation does not support this initiative;
- Citizens – the priorities of citizens most times will define how the public funds are invested, it is important to promote the right deployments.

Turning cities into smart cities is a matter of changing the mindset of their decision makers, empowering citizens with information and technology, as well as with the possibility to cooperate within cities decisions through participatory budgets/projects. Along with this process it is important to study what has been implemented for other cities and exchange best practices to not commit the same mistakes (this is one of the reasons why EC funding programmes usually take only into account consortium application containing entities from different cities of different countries).

In Figure 25, it is described the process in which steps are described below.

All cities have complex ecosystems with distinct dynamics. There is not any uniform and replicable secret to appl. In order to a city be able to adopt this “Smart City mindset” in its daily activity, first needs to know which verticals already exist, how its management is done, verifying the infrastructure already deployed and understand the results that are currently being obtained, in order to identify the main problems and points of action - "Knowing our city".

Although recent, the theme of Smart Cities is not a new theme, and therefore there are cities that have already gone through this process. The study of "best practices" and getting advice from those who have coexisted with these projects is something that should not be forgotten nor undervalued - "Study of Best Practices".

Following the in-depth study of the city you are focusing your efforts and of what has already been implemented in others, the next step is to define priorities according to the needs of the citizens and the market to better manage the entire ecosystem - "Defining Priorities".

The governance of a city is made up of electoral cycles. What does not change is the people who inhabit it. In the planning of the strategy to be adopted by the decision makers of these ecosystems, it is necessary to listen to the different "Stakeholders", never underrating, in the final decision, the importance of the "citizen's voice"! Who better than the people who daily use the various systems of the city to identify the actual needs? - "Involve Stakeholders".

For a better evaluation of the measures and solutions to be implemented, it is not enough just taking the advice from cities that have already made some of these changes. It is necessary to analyse the market and look for partners (mainly technological) capable of responding to the needs identified in the previous points. The creation of partner networks depending on the project and area concerned will give greater insight into the market. - "Market Analysis".

For the adoption of an intelligent solution in a certain vertical of a city it is necessary to study the capacity to be satisfied the following three points: data collection systems (sensors, cameras...), connectivity (networks, communication protocols available on the region...) platform and mobile applications to make the data available to system administrators and "end-users". The best solutions have these points well defined and the integration between them very clear. - "Solutions Choice".

After identifying the best solutions, pilot projects are implemented for a short period of time (usually periods of three, six or twelve month projects), in order to understand and compare the improvements achieved with the introduction of the different types of technology in the daily life of the city. Sometimes these pilot projects, considering the deployment of different devices (from different areas/verticals) are implemented in a certain location of the city – Living Lab - to study in real time the impacts of the aggregation of the collected information - "Pilot Projects".

However, pilot projects are nothing more than a proof of concept in a real environment. If they are successful, i.e. that there are significant improvements identified after the pilot agreed period, they tend to be implemented on a global scale throughout the city. The results obtained during the pilot phase will define the scale of the new (after) project - "Scale Projects".

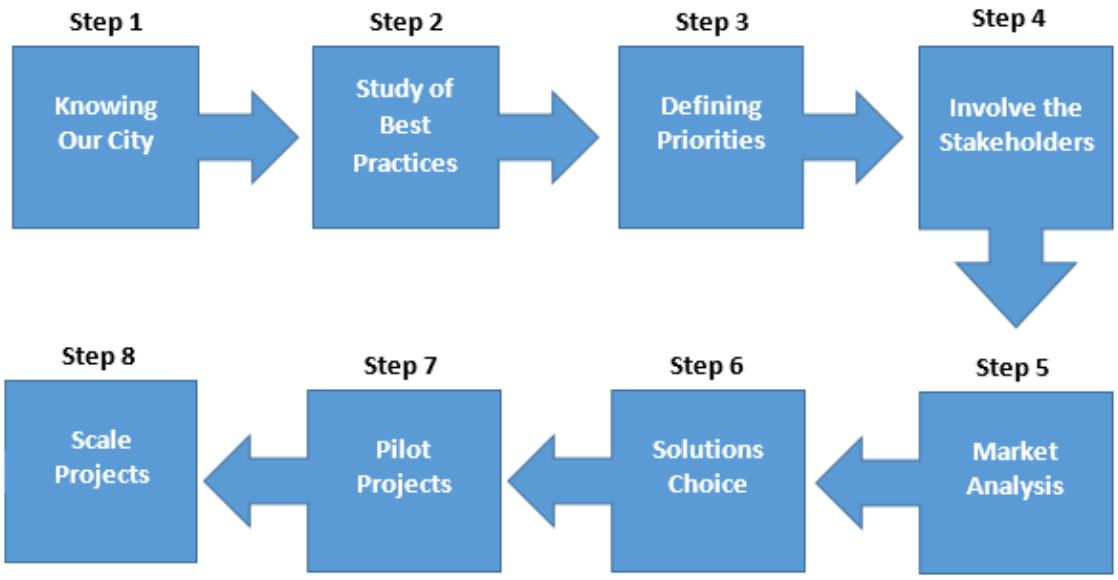

Fig. 25 - *Process behind the adoption of a Smart City strategy.*

One of the conclusions the audience has achieved at the conference was that there is no line which separates cities from Smart Cities. Smartness is how it is used the collected data from every single source available and how this information it is treated to better advise cites administrations and help citizens' in their daily life.

With the nowadays digitization it is normal the processes are becoming more and more digital, however a Smart City it is not a Digital City, a Smart City is a city that uses the latest technology to improve some of its processes which will generate a gain in people's quality of life.

It is important to understand what are the existing resources and services in the city to define the strategy with the relevant solutions and use cases which can bring a direct improvement on peoples' lives.

4.1 Results Limitations

Some limitations that can be pointed to the obtained results are the fact that more than 50% of the respondents do not work directly with the Smart Cities theme, which presupposes that many may not really be aware of what is being implemented in cities around the world, which has a clear impact for example on the question about the Smartest solution that was implemented in the opinion of the respondents. Adding that to the fact that almost all the population that responded to the questionnaire live in Portugal, it is not possible to have a more general view from the opinions of citizens of other regions. In addition to a possible non-representativeness, another limiting factor in this questionnaire is that it was very extensive in terms of the KPIs to be evaluated, which may have meant that the analysis and evaluation by the respondents had not been so attentive and precise.

5. Conclusions and Future Work

Smart cities exist for a long time. The term “Smart Cities” comes from the intelligent measures taken on behalf of urban planning. Nowadays, the difference is that until now cities were reactive rather than proactive, and real time data solutions are changing this mindset. Having fundamental data to take an action on an urban development level is a considerable improvement which cities can count from now on.

As we saw in the analysis of the cities throughout the world, the maturity of solutions and the priorities/roadmap to implement these solutions are very different from one city to another, from one continent to another. Additionally, what is a Smart City for a citizen in a certain region is totally different from what it is in another. It is important to look at the different realities when we are assuming that a city is smarter than another.

The discussion about the theme will always exist, more and more, mostly because of the mega projects that are being invested by some governments, like the Asian cities built from the scratch. This leads to an even bigger discussion of if the money used to enhance that project should not have been used to improve the conditions of living at some other parts of the continent, where the quality of life is miserable.

The developed optimized tool built in this document should be considered in these cases to understand what should be the priority areas/focus of city administrations.

A city must not be considered smart just for its politics to acquire brand new technology. Making a comparison with the daily life, the previous statement would be the same as saying that a rich person is a happy person. We should not confuse this, because that way the city decisions and companies’ interests would overcome citizens’.

“Progressive smart cities must seriously start with people and the human capital side of the question, rather than blindly believing that IT itself automatically transform and improve cities” (Hollands 2008).

This sentence was at the base of the willingness of the author to write the present document. The present work had the opportunity of listening to citizens’ voice and understanding what their opinion is regarding what a city should take into the account to declare itself as smart and what are the most important KPIs from the ones defined by reference entities in the area. To be able to do that, it was finally, with the gathered results, designed a formula which pretends to be a standard and normalised way to evaluate cities.

The fact that it was driven an inquiry, with the representativeness of 57 respondents where almost 50 % of them work (or have worked) in the area, makes the results reliable and let us be able to consider the obtained values of the coefficients in the final equation.

One of the most interesting conclusions we can take with this work comes with the analysis of the value of the different coefficients. If the reader take a closer look, it is possible to see that what sometimes we assume as true it is not (like the importance of gender equity).

“Clearly, a large-scale, platform-independent, diverse-application IoT infrastructure can aid this process by including data processing and management, actuation, and analytics. With advanced sensing and computation capabilities, data are gathered and evaluated in real time to extract the information, which is further converted to usable knowledge. This will enhance the decision making of city management and citizens to turn the city smart.” (Jin et al., 2014)

Technology is here to stay. Data without any deep analytics is just trash. Raw data will be only useful for cities if they have the ability to analyse it and integrated with other sources of data to create more information with that.

Despite the existence of a lot of barriers and challenges which have to be taken into account, the focus of the smart city must be its community and how technology can simplify their life, because if we do not have the perfect combination between decision makers and citizens, cities will not be able to improve its citizens’ quality of life which is the main purpose of every new technology that is introduced.

As a matter of future work, more than make a deeper analysis on the different existing initiatives and get the opinion from experts about what will be the direction which Smart Cities will go for, should be made the identification of several cities and evaluate their indexes. After that analysis, it would be important to calculate the correlation between variables and study what is already deployed in them and what are the actions that must be taken to improve the value of their KPIs and consequently the index value.

You can introduce brand new technology, but if citizens do not find it has an improvement in their daily life they will not adopt it.

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Annex

Annex 1 – Inquiry Structure

What defines a Smart City?

Inquiry in the framework of the Master Thesis "Optimized tool for the evaluation of the Smart City Index" by Diogo Correia

What defines a Smart City? What does it take to say that a certain City is smarter than another? The aim of the present inquiry is to get the opinion about the importance of each KPI of the Smart City Index and its sub-dimensions (used by reference entities as ISO , IEC , ITU , ETSI or NIST and some I have identified myself) through a Likert scale analysis to take into account in the definition of an optimize tool for the evaluation of the smart city level of a city. A tool that is not just focused on the results got from each KPI but is also interested on what us, citizens, think that the result of a certain KPI means when we are talking about what truly matters to declare a city as a Smart City.

Note: Please answer in English, Portuguese or Spanish. If you want to have the possibility to be quoted in the final document please leave your personal details at the bottom. Only me and the judges at the final presentation will have the access to your personal data.

1. **Age** *

- ◯ 18 - 25
- ◯ 26 - 40
- ◯ 41 - 60
- ◯ + 60

2. **Gender** *

- ◯ Male
- ◯ Female

3. **Is your current job (or one of your jobs was) related to the Smart Cities theme?** *

- ◯ Yes
- ◯ No

4. **What is your Nationality?** *

5. **Which city do you live in?** *

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Fig. 26 – *First page of the inquiry where are pointed questions related to personal details of the respondents.*

6. **What does "Smart City" stand for you?** *

7. **Does the implemented technology in a city defines a Smart City?** *

- Yes
- No

8. **What was the smartest solution your city has adopted?**

KPIs - Level of Importance

Please give your opinion about the level of importance of each KPI to calculate its coefficient on the final equation of index of the City.
1 - Not Important
2 - Slightly Important
3 - Moderately Important
4 - Important
5 - Very Important

9. **1) People - Health** *

	1	2	3	4	5
Access to basic health care - Share of population with access to basic health care services within 500m					
Level of satisfaction with health care service					
Encouraging a healthy lifestyle - The extent to which policy efforts are undertaken to encourage a healthy lifestyle					
Life Expectancy in the city					
Number of in-patient hospital beds per 100 000 population					

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Fig. 27 – *Second page of the inquiry where are pointed questions related to the Smart Cities theme and where begins the assessment of the KPIs with the first Sub Dimension ("Health") of the Dimension "People".*

10. **1) People - Safety** *

	1	2	3	4	5
Traffic accidents - Number of transportation fatalities per 100.000 population					
Crime rate - Number of violence, annoyances and crimes per 100.000 populatio					
Number of police officers per 100 000 population					
Personal safety - Level of safeness felt					
Cybersecurity - The level of cybersecurity of the cities' systems					
Data privacy - The level of data protection by the city					

11. **1) People - Mobility** *

	1	2	3	4	5
Use of electrical cars - Share of population using electrical cars					
Access to public transport - Share of population with access to a public transport stop within 500m					
Annual number of public transport trips per capita					
Number of personal automobiles per capita					
Level of satisfaction felt with the conditions of the public transportation					
International accessibility - Share of population with access to international transport					
Access to vehicle sharing solutions for city travel					
Length the bike route network - % of bicycle paths and lanes in relation to the length of streets (excluding motorways)					

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Fig. 28 *–Assessment of the KPIs of the Sub Dimensions "Safety" and "Mobility" that make part of the Dimension "People".*

12. **1) People - Access to other services** *

	1	2	3	4	5
Access to public amenities - Share of population with access to at least one type of public amenity within 500m					
Access to commercial amenities - Share of population with access to at least six types of commercial amenities providing goods for daily use within 500 m					
Access to cultural facilities - Cinema/museum/theater attendance per inhabitant					
Access to high speed internet - Fixed (wired)-broadband subscriptions per 100 inhabitants					
Satisfaction with the quality of the services provided by the mobile operators					
Satisfaction with WiFi network in the region					
Access to public free WiFi - Public space Wi-Fi coverage					

13. **1) People - Education** *

	1	2	3	4	5
Access to educational resources - The extent to which the city provides easy access (either physically or digitally) to a wide coverage of educational resources					
Satisfaction with education policies and conditions - Level of satisfaction with the teacing mode and the facilities conditions provided by the city					
Open-mindedness - Immigration-friendly environment (attitude towards immigration)					
Digital literacy - Percentage of target group reached					

14. **1) People - Quality of housing and the built environment** *

	1	2	3	4	5
Diversity of housing types - Simpson Diversity Index of total housing stock in the citystock in the area					
Preservation of cultural heritage - The extent to which preservation of cultural heritage of the city is considered in urban planning					
Green space - Green hectares/ 100.000 population					

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Fig. 29 – *Assessment of the KPIs of the Sub Dimensions "Access to other services", "Education" and "Quality of housing and the built environment" that make part of the Dimension "People".*

15. **2) Planet - Energy and Mitigation** *

	1	2	3	4	5
Energy consumption/demand - Annual final energy consumption for all uses and forms of energy	◯	◯	◯	◯	◯
Satisfaction with the service provided by energy providers and distributors	◯	◯	◯	◯	◯
Renewable energy production - The percentage of total energy derived from renewable sources, as a share of the city's total energy consumption	◯	◯	◯	◯	◯
CO2 emissions in tonnes per capita per year	◯	◯	◯	◯	◯
Local freight transport fuel mix - The ratio of renewable fuels in the local freight transport fuel mix	◯	◯	◯	◯	◯

16. **2) Planet - Materials Water and Land** *

	1	2	3	4	5
Domestic material consumption - The total amount of material directly used in the city per capita	◯	◯	◯	◯	◯
Potable Water - Percentage of population with potable water supply service	◯	◯	◯	◯	◯
Total Water consumption per capita per day	◯	◯	◯	◯	◯
Grey and rain water reuse - Percentage of houses equipped to reuse grey and rain water	◯	◯	◯	◯	◯
Water Exploitation Index - Annual total water abstraction as a percentage of available long-term freshwater resources in the geographically relevant area (basin) from which the city gets its water	◯	◯	◯	◯	◯
Percentage of water loss of the total water consumption	◯	◯	◯	◯	◯
Population density - Number of people per km2	◯	◯	◯	◯	◯
Local food production - Share of food consumption produced within a radius of 100 km	◯	◯	◯	◯	◯

17. **2) Planet - Climate resilience** *

	1	2	3	4	5
Climate resilience strategy - The extent to which the city has developed and implemented a climate resilient strategy	◯	◯	◯	◯	◯
Urban Heat - Maximum difference in air temperature within the city compared to the countryside during the summer months	◯	◯	◯	◯	◯

5/11

Fig. 30 *– Assessment of the KPIs of the Sub Dimensions "Energy and mitigation", "Materials, water and land" and "Climate resilience" that make part of the Dimension "Planet".*

18. **2) Planet - Pollution and waste** *

	1	2	3	4	5
Annual nitrogen oxide emissions (NO and NO2) per capita	◯	◯	◯	◯	◯
Annual particulate matter emissions (PM 2,5) per capita	◯	◯	◯	◯	◯
Respiratory diseases - Percentage of fatal chronic lower respiratory diseases	◯	◯	◯	◯	◯
Air quality index - Annual concentration of relevant air pollutants	◯	◯	◯	◯	◯
Noise pollution - Share of the population affected by noise >55 dB(a) at night time	◯	◯	◯	◯	◯
The amount of municipal solid waste generated per capita annually	◯	◯	◯	◯	◯
Recycling rate - Percentage of city's solid waste that is recycled	◯	◯	◯	◯	◯

19. **2) Planet - Ecosystem** *

	1	2	3	4	5
Share of green and water surface area as percentage of total land area	◯	◯	◯	◯	◯
Percentage change in number of native species	◯	◯	◯	◯	◯
Increased ecosystem quality and biodiversity - The extent to which ecosystem quality and biodiversity aspects have been taken into account	◯	◯	◯	◯	◯

20. **3) Prosperity - Employment** *

	1	2	3	4	5
Uneployment rate - Percentage of the labour force unemployed	◯	◯	◯	◯	◯
Youth unemployment rate - Percentage of youth labour force unemployed	◯	◯	◯	◯	◯

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Fig. 31 *– Assessment of the KPIs of the Sub Dimensions "Pollution and waste" and "Ecosystem" that make part of the Dimension "People" and the Sub Dimension "Employment", the first one of the "Prosperity" Dimension.*

21. **3) Prosperity - Equity** *

	1	2	3	4	5
Fuel poverty - The percentage of households unable to afford the most basic levels of energy					
Economic power - Capability to don't just afford basic needs					
Gender equity - Level of gender equity felt					
Poverty rate - The percentage of homeless people leaving in the city					
Affordability of housing - % of population living in affordable housing					

22. **3) Prosperity - Green Economy** *

	1	2	3	4	5
Share of certified companies - Share of companies based in the city holding an ISO 14001 certificate					
Share of Green Public Procurement - Percentage annual procurement using environmental criteria as share of total annual procurement of the city administration					
Green jobs - Share of jobs related to environmental service activities that contribute substantially to preserving or restoring environmental quality					
Freight movement - Freight movement is defined as the number of freight vehicles moving into an area (e.g. the city)					

23. **3) Prosperity - Economic Performance** *

	1	2	3	4	5
Gross Domestic Product - City's gross domestic product per capita					
Debt service expenditure as a % of a municipality's own-source revenue					
New business registered - Number of new businesses per 100,000 population					
International embeddedness - Percentage of companies with headquartered in the city quoted on national stock market					

7/11

Fig. 32 *– Assessment of the KPIs of the Sub Dimensions "Equity", "Green economy" and "Economic performance" that make part of the Dimension "Prosperity".*

24. **3) Prosperity - Innovation** *

	1	2	3	4	5
Creative industry - Share of people working in creative industries					
Number of innovation hubs in the city, whether private or public, per 100.000 inhabitants					
Accessibility of open data sets - The extent to which the open city data are easy to use					
Research intensity - R&D expenditure as percentage of city's GDP					
Patent applications - Number of registered patent applications per inhabitant					
Open data - # of open government datasets per 100.000 inhabitants					

25. **3) Prosperity - Attractiveness & competitiveness** *

	1	2	3	4	5
Congestion - Increase in overall travel times when compared to free flow situation (uncongested situation)					
Public transport use - Annual number of public transport trips per capita					
Net migration - Rate of population change due to migration per 1000 inhabitants					
Population Dependency Ratio - Number of economically dependent persons (net consumers) per 100 economically active persons (net producers)					
Tourism intensity - Number of tourist nights per year per 100.000 inhabitants					

8/11

Fig. 33 *– Assessment of the KPIs of the Sub Dimensions "Innovation" and "Attractiveness and competitiveness" that make part of the Dimension "Prosperity".*

26. **4) Governance - Organisation** *

	1	2	3	4	5
Transparent Governance - Satisfaction with transparency of bureaucracy and with fight against corruption					
Cross-departmental integration - The extent to which administrative departments contribute to “smart city” initiatives and management					
Establishment within the administration - The extent to wich the smart city strategy has been assigned to one department/director and staf resources have been alloated					
Monitoring and evaluation - The extent to which the progress towards a smart city and compliance with requirements is being monitored and reported					
Availability of government data - The extent to which government information is published					
Female participation in decision-making - Share of female city representatives					

27. **4) Governance - Community involvement** *

	1	2	3	4	5
Open public participation - Number of public participation processes per 100.000 per year					
Voter participation - % of people that voted in the last municipal election as share of total population eligible to vote					

28. **4) Governance - Multi-level governance** *

	1	2	3	4	5
Smart city policy - The extent to which the city has a supportive smart city policy					
Expenditures by the municipality for a transition towards a smart city - Annual expenditures by the municipality for a transition towards a smart city					
Multilevel government - The extent to which the city cooperates with other authorities from different levels					

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Fig. 34 *– Assessment of the KPIs of the Sub Dimensions “Organisation”, “Community involvement” and “Multi-level governance” that make part of the Dimension “Governance”.*

29. **Is there any KPI you think it must be added to this list?**

Subdimensions - Level of Importance

Please give your opinion about the level of importance of each subdimension to calculate its coefficient on the final equation of index of the City.
1 - Not Important
2 - Slightly Important
3 - Moderately Important
4 - Important
5 - Very Important

30. **1) People** *

	1	2	3	4	5
Health					
Safety					
Mobility					
Access to other services					
Education					
Quality of housing and the built environment					

31. **2) Planet** *

	1	2	3	4	5
Energy and Mitigation					
Materials Water and Land					
Climate resilience					
Pollution and waste					
Ecosystem					

32. **3) Prosperity** *

	1	2	3	4	5
Employment					
Equity					
Green economy					
Economic Performance					
Innovation					
Attractiveness & competitiveness					

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Fig. 35 *– Question about respondents' opinion about if there is any KPI they think that should be added to the list. Assessment of the Sub Dimensions of the "People", "Planet" and "Prosperity" Dimensions.*

33. **4) Governance** *

	1	2	3	4	5
Organisation					
Community involvement					
Multi-level governance					

34. **Name**

35. **Position**

36. **Entity**

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Fig. 36 *– Assessment of the Sub Dimensions of the "Governance" Dimension.*

Annex 2 – Graphical global answers to the KPIs evaluation

i. People

a. Health

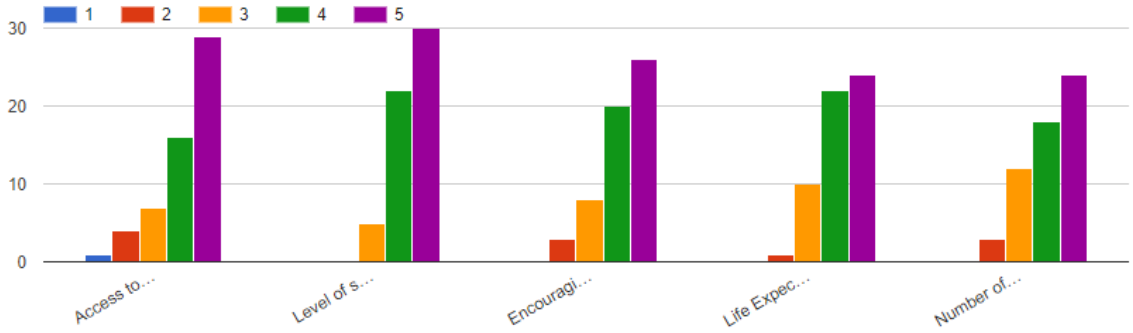

Fig. 37 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Health" that constitutes the "People" Dimension.*

b. Safety

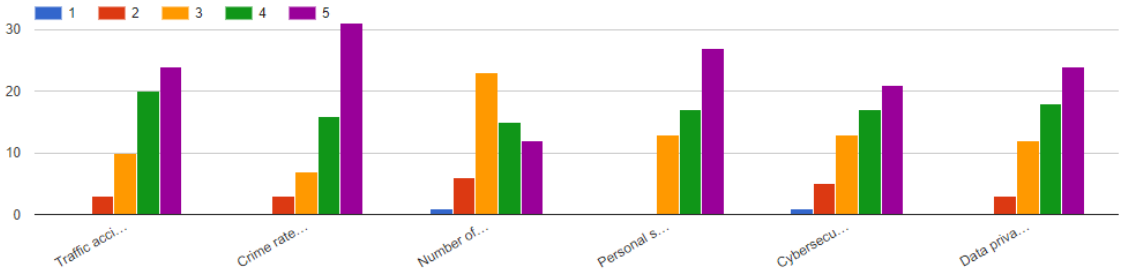

Fig. 38 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Safety" that constitutes the "People" Dimension.*

c. Mobility

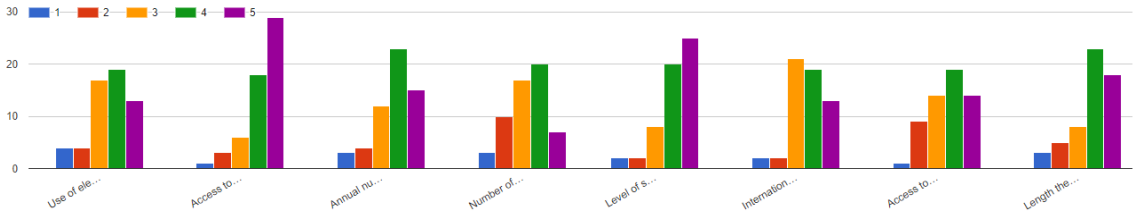

Fig. 39 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Mobility" that constitutes the "People" Dimension.*

d. Access to other services

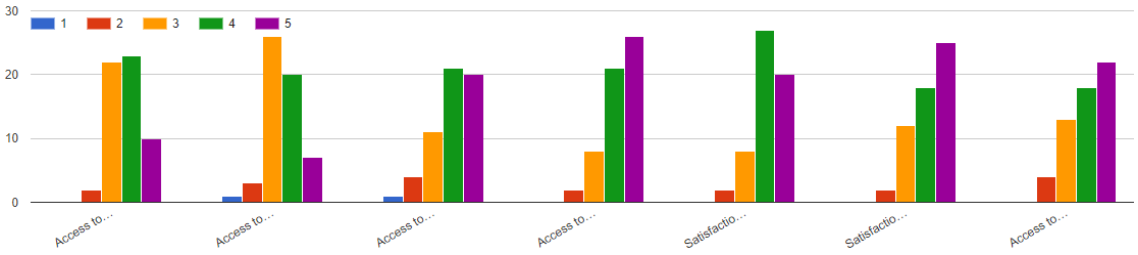

Fig. 40 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Access to other services" that constitutes the "People" Dimension.*

e. Education

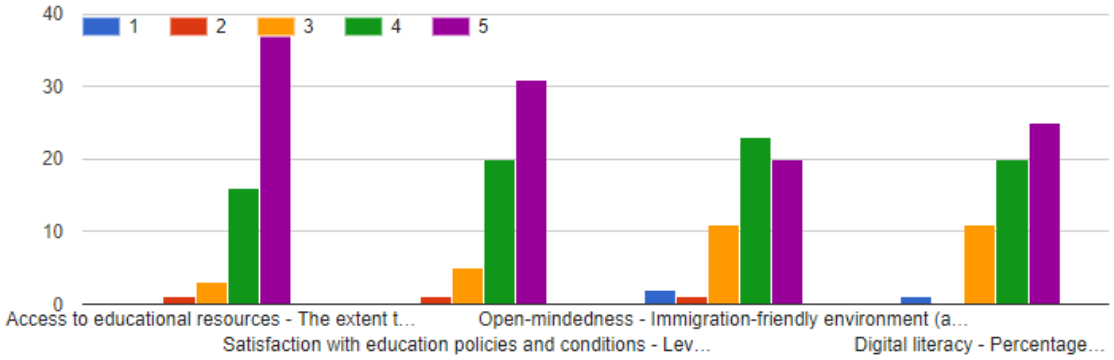

Fig. 41 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Education" that constitutes the "People" Dimension.*

f. Quality of housing and the built environment

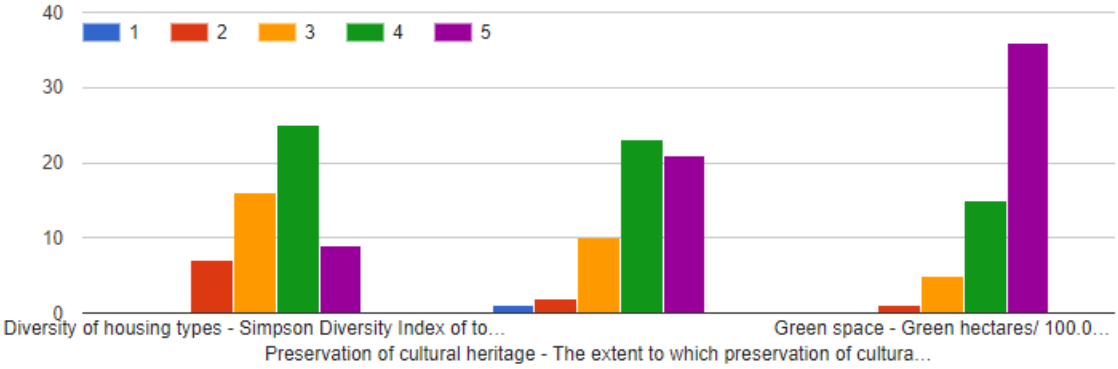

Fig. 42 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Quality of housing and the built environment" that constitutes the "People" Dimension.*

ii. Planet

a. Energy and mitigation

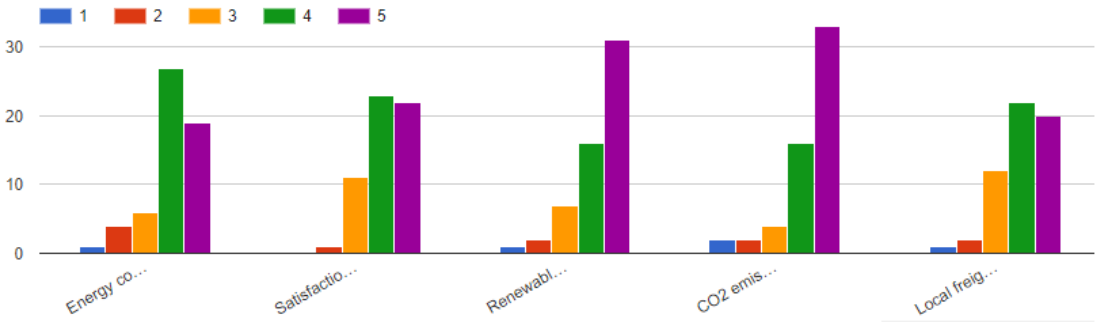

Fig. 43 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Energy and mitigation" that constitutes the "Planet" Dimension.*

b. Materials, water and land

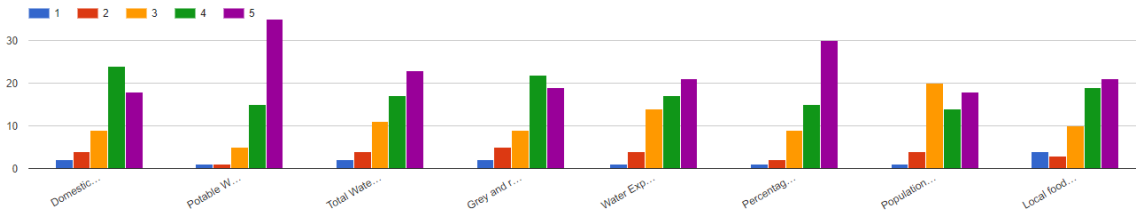

Fig. 44 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Materials, water and land" that constitutes the "Planet" Dimension.*

c. Climate resilience

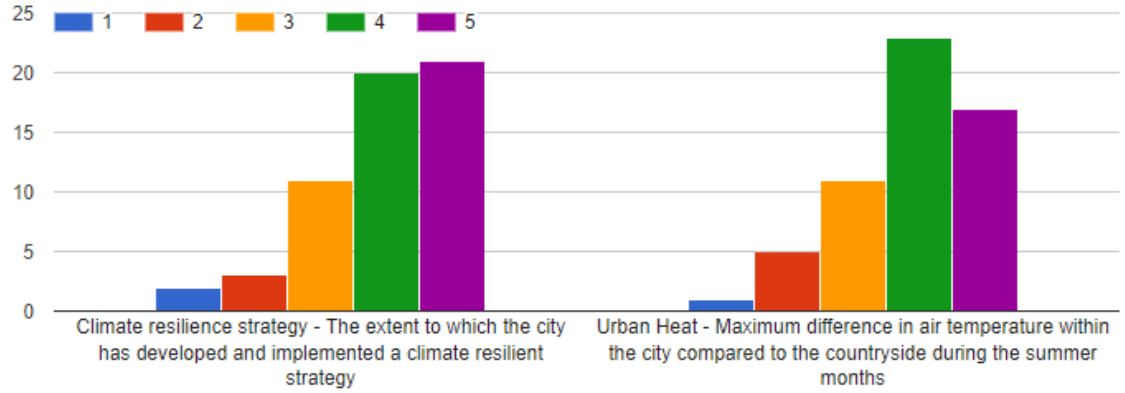

Fig. 45 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Climate resilience" that constitutes the "Planet" Dimension.*

d. Pollution and waste

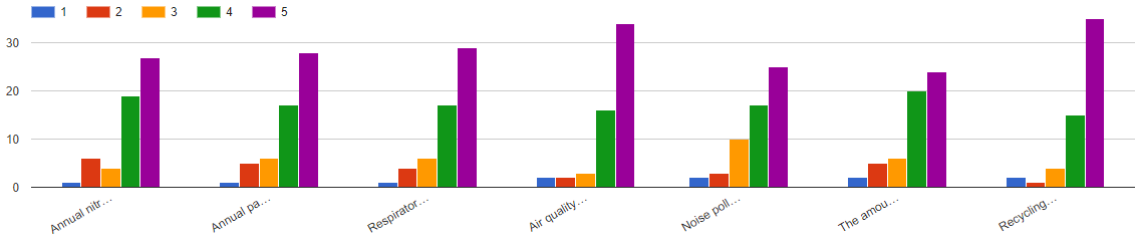

Fig. 46 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Pollution and waste" that constitutes the "Planet" Dimension.*

e. Ecosystem

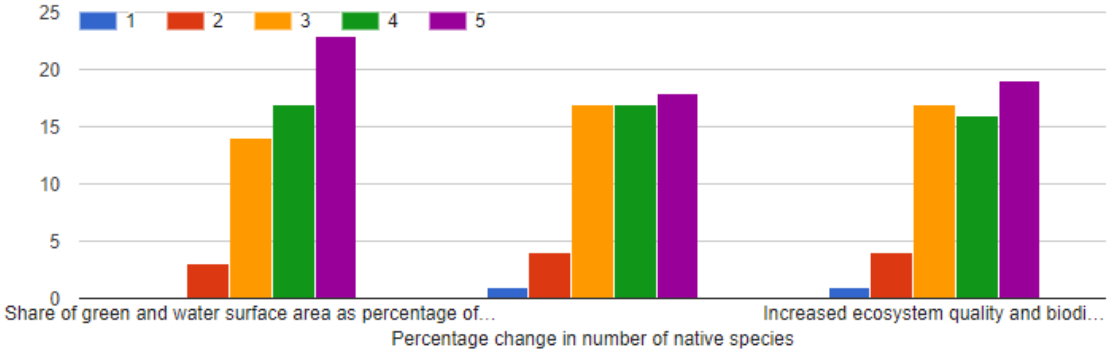

Fig. 47 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Ecosystem" that constitutes the "Planet" Dimension.*

iii. Prosperity

a. Employment

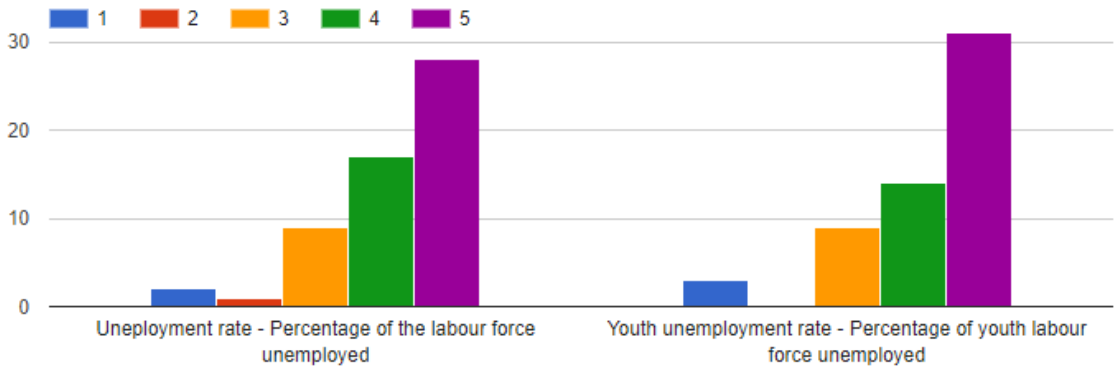

Fig. 48 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Employment" that constitutes the "Prosperity" Dimension.*

b. Equity

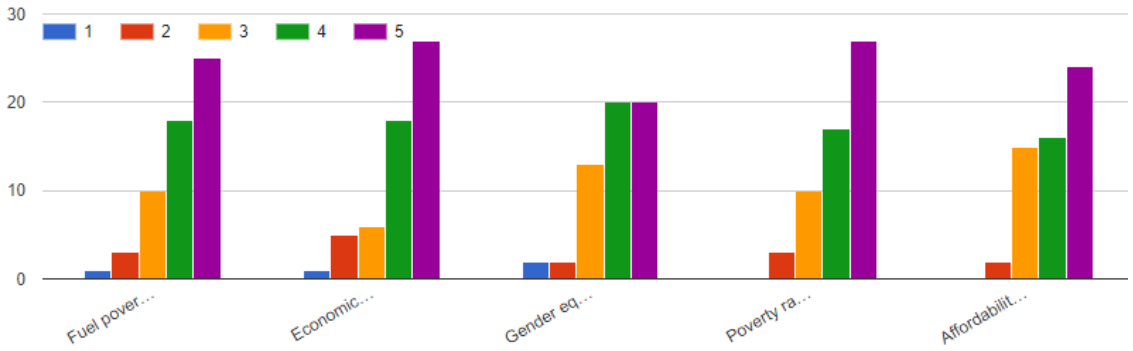

Fig. 49 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Equity" that constitutes the "Prosperity" Dimension.*

c. Green economy

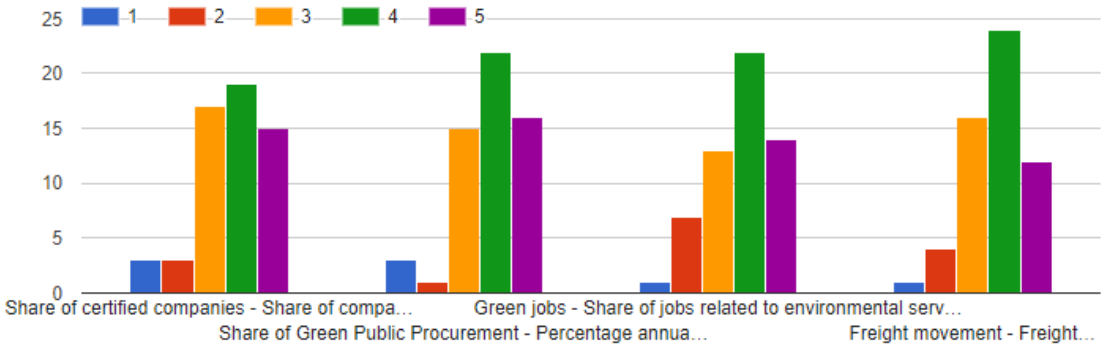

Fig. 50 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Green economy" that constitutes the "Prosperity" Dimension.*

d. Economic performance

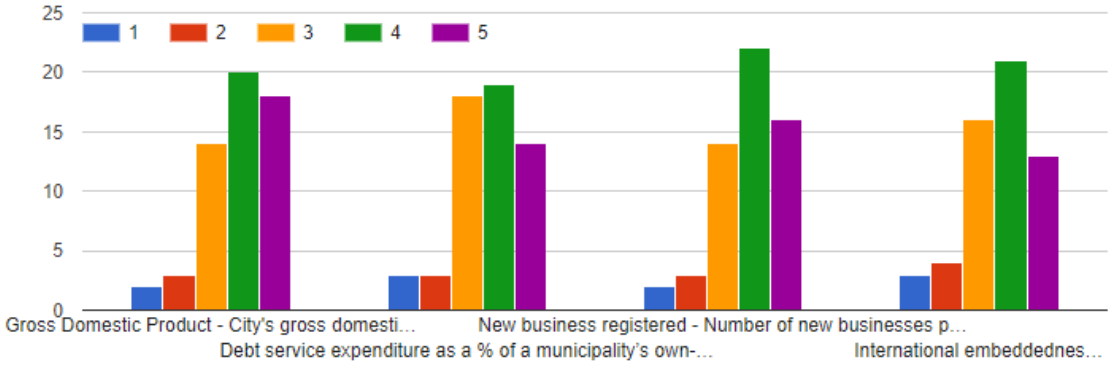

Fig. 51 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Economic performance" that constitutes the "Prosperity" Dimension.*

e. Innovation

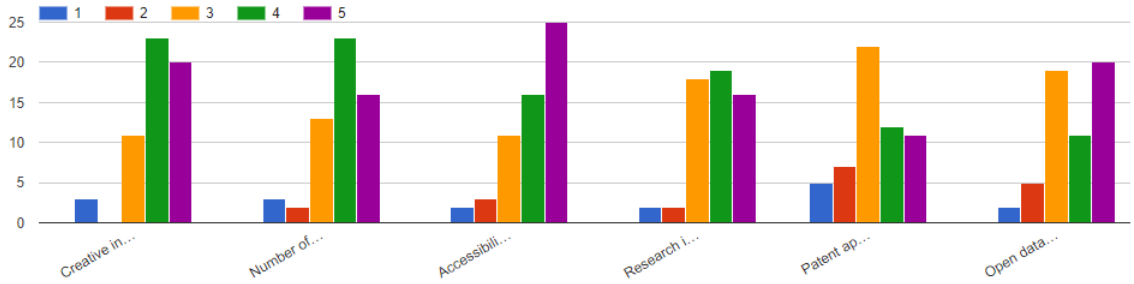

Fig. 52 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Innovation" that constitutes the "Prosperity" Dimension.*

f. Attractiveness and competitiveness

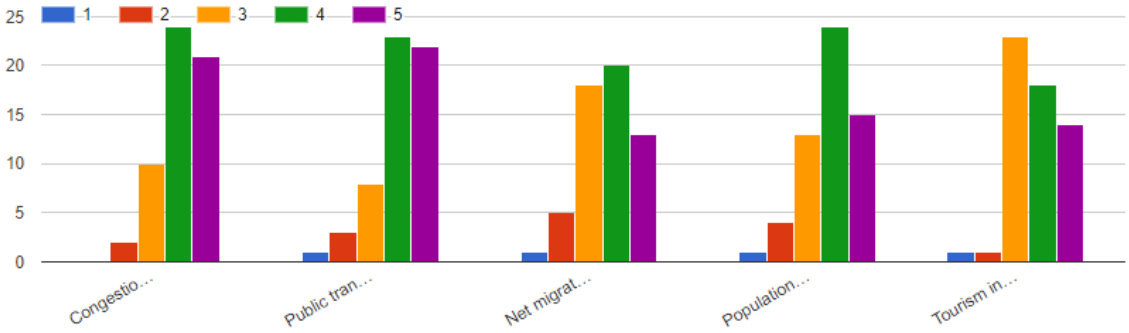

Fig. 53 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Attractiveness and competitiveness" that constitutes the "Prosperity" Dimension.*

iv. Governance

a. Organisation

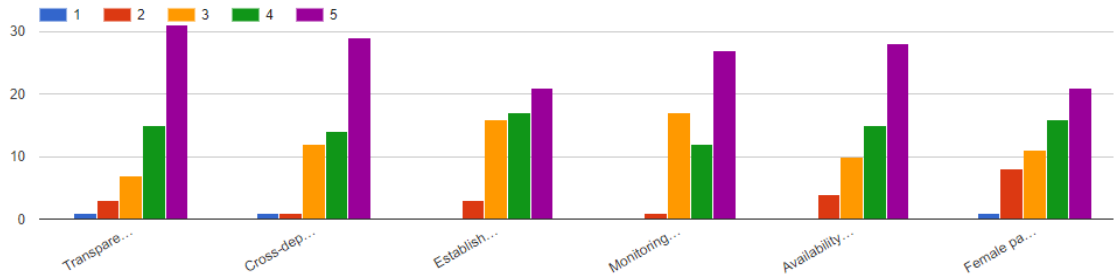

Fig. 54 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Organisation" that constitutes the "Governance" Dimension.*

b. Community involvement

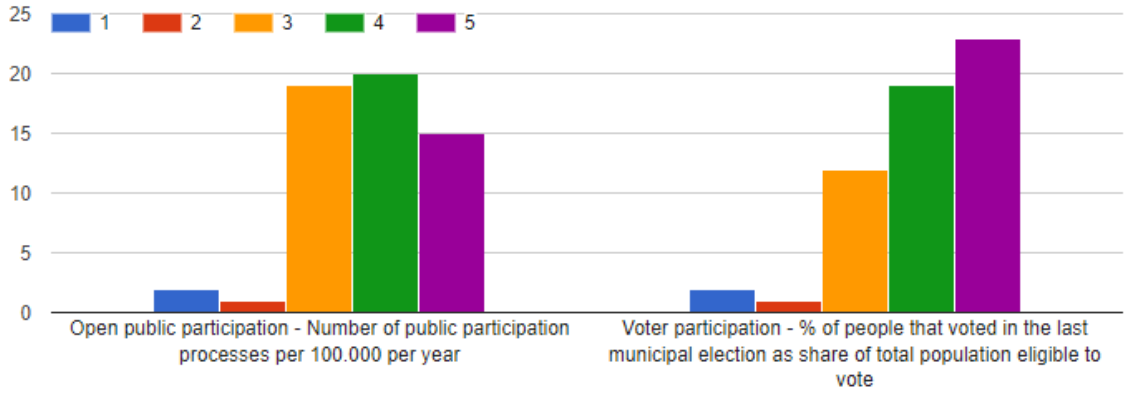

Fig. 55 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Community involvement" that constitutes the "Governance" Dimension.*

c. Multi-level governance

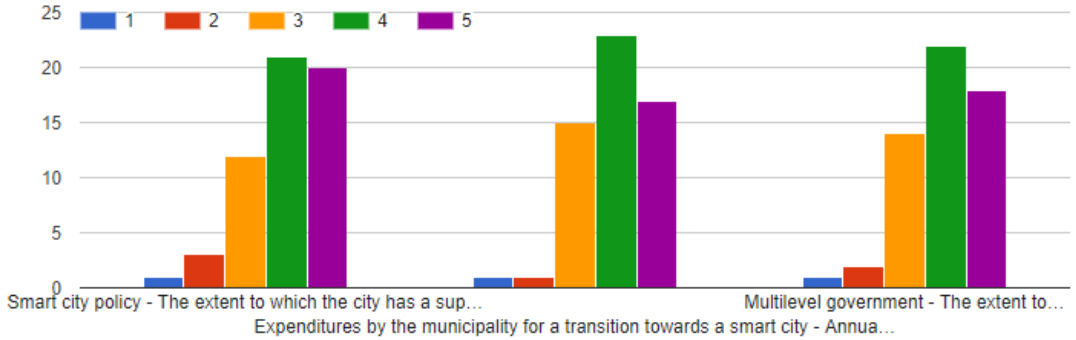

Fig. 56 – *Graphical distribution of the assessment made to the KPIs of the Sub Dimension "Multi-level governance" that constitutes the "Governance" Dimension.*