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The Spread of Smart Cities in Brazil - Focus on adopted technologies

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To my grandma.

«D'una città non godi le sette o settantasette meraviglie, ma la risposta che dà a una tua domanda.»

Italo Calvino, Le Città Invisibili

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Abstract

In the last decades, the increase in demographic density led to the creation of new needs. The population boom has created different necessities aimed at trying to solve some problems that this rise has involved. The issues that should be faced concern different fields, from transportation to healthcare to energy. Therefore, cities have started to revolutionize their infrastructure for solving these problematic aspects and for satisfying the needs of citizens, that have become pretentious as they got in touch with new technologies. This is the context where the concept of *Smart City* comes from. Although a unique definition of Smart City does not exist, it can be defined as a city that takes advantages by using digital solution in order to improve the quality life of inhabitants optimizing services, resources and infrastructures. The problem is that there is still difficulty in identifying which aspects should be observed to classify or not a SC. The concept of SC and of *smartness* are not still clear, as it was seen that several independent and external aspects influence it. Culture, size, economic and technological development and other country specific-factors all influence the taxonomy, leading to potential incorrect results.

The aim of this thesis is to apply the taxonomy defined by Perboli et al. (2014) to analyse some SCPs, in order to identify a trend of the territory in analysis, in our case Brazil. As results, we should be able to highlight the success factors that cities should implement in their strategies and business model to improve the citizen quality life.

Table of Contents

List of Figures

List of Tables

Introduction

Nowadays, the theme of *Smart City* is at the centre of many discussions. It is noticeable that the revolution of cities' infrastructure would lead to the optimization of resources, to increase the efficiency of services and to reduce the waste of energy and money.

The introduction of SC is aimed at solving the problems linked to the population boom, such as the increase in pollution, the rise in traffic congestion, and other problems concerning the different aspects (energy, education, healthcare, transportation, public security, etc.).

In this context, a central topic that has drawn attention regards the sustainability, both economic, social and environmental. For instance, in terms of environmental sustainability, over the years the advances in urbanization and industrialization have caused catastrophic environmental damages, from the poor air quality, to the increase of ozone hole and to the water pollution. Smart Cities, hence, are proposed to offer sustainable approaches for safeguarding the environment, such as tracking and weighting the solid waste and charging the user for the amount of non-recyclable material thrown away. As results, citizens are incentivized to decrease the production of unrecycled solid waste.

A common mistake people are used to do is to associate the concept of Smart Cities with the term Information and Communication Technology (ICT). Thinking at cities' smartness we do not have to think solely about technological innovation. ICT and digital solutions are input tools that contribute to reshape the urban system. In fact, the main purpose of Smart Cities projects is to meet citizens' necessities improving standard living and quality life. Human capital plays a key role. However, there is not a unique way to identify and classify a city as *smart*. it is due to the fact that cities are complex systems characterized by different needs and contextual conditions (i.e. the level of economic or educational development or the size and demographic density). For this reason, a universally accepted taxonomy does not exist. There have been some efforts to determine a standardized classification of the features characterizing a SC, but so far it has not been already agreed due to the previously mentioned issues.

However, three common layers have been detected to foster the implementation of SCs.

Firstly, the spread of technology base, including the mass diffusion of smart devices and other smart sensors. These sensors are always connected by high-speed networks to improve the communication quality and it allows a continuous information sharing on the real-time

base. The gathered information regards data about traffic, pollution, energy consumption, heart-beats, and all other fields that could improve the quality life of citizens.

Secondly, managing of collected data in specific applications to provide insights and preventive actions. The developed technologies and applications translate input information recorded by the smart sensors into useful ideas and suggestions for several domains, such as security, mobility and waste.

Thirdly, the public usage of these specific applications enables the collection of that data by large source. In this way, the more the specific applications are broadly used, the more data are gathered and the more the cities are able to convert recorded data and to provide improvements in urban system. It happens because, having a large amount of data from citizens, cities may lend more detailed and punctual solutions for daily problems.

The thesis aims to analyse the situation of the SCs in the Brazilian territory, paying attention to all the axes defined by Perboli et al. (2014).

In Chapter 1, we will present an overview of the evolution of the concept of *city*, reporting all the elements that derived its growth.

In Chapter 2, we created an overview of the Brazilian scenario, taking into consideration economic and social elements

In Chapter 3, we will analyse different categorisations of SCs, we will explain the reason for their failure, and we will resume the taxonomy produced by Perboli et al. (2014), analysing it in detail, to apply it to a sample of 50 SCPs in the South American state.

In Chapter 4, we will try to detect some recurring pattern with respect to the Objectives / Tools categories, based on the taxonomy's application results, and will focus on the tools adopted in one of the 50 projects analysed, identifying which and how they have been implemented.

Chapter 1
What are Smart Cities?

Let's start by saying that the answer to this question is not simple. Each of us would give different answers to each other and the whole of them would still be incomplete and not definitive. Perhaps only by considering their summation would we have a clearer view of the complexity behind this definition but as said yet not exhaustive.

The history of Smart Cities starts from far away and in order to fully understand their genesis we must disturb sociology to understand certain demographic behaviours that have affected our last century.

Once identified in Urbanism and in its causes the lever that justifies the great increase in the population of urban areas, it is necessary to identify in the technology available the catalysing agent and the tool to solve problems to which cities were forced to respond.

Finally, depending on what we discover by analysing the above, we will have to understand how we can measure the degree of Smartness of a city. Perhaps, only and only from this analysis of the measurement indexes, we will be able to understand which services the citizens deem necessary to define their Smart City and hence its final definition that originates from the construction of a strategic, organic and planned Vision, connected to the ability to read the potential of territories, by an organism able to rethink the city with a long-term vision and an integrated approach.

1.1 The Urbanism

The Urbanism may be seen as the immigration from the countryside and from small towns to large cities of large masses, mostly rural, coming from both the surrounding area and from even distant areas. It is the cause of profound transformations and often, if too rapid and

uncontrolled, of serious demographic, economic, social, cultural and even customs imbalances.

Urbanism, as modernly understood and defined, developed only from the 19th century, as a consequence of the industrial revolution: this initially had as a binding localization factor the presence of deposits of raw materials, towards which large flows were directed migrants from the countryside, giving rise to monocentric urban agglomerations. The heart of Urbanism, it was, therefore, first Western Europe; the connected development of maritime and land transport (railways), with the consequent intensification of trade, then led to the expansion of the phenomenon to countries that gradually reached the stage of industrial take-off, first of all the United States.

The urbanism of industrial countries is fomented by economic imbalances between the rural environment and the most advanced and dynamic cities. Industrial development has attracted manpower by offering new jobs in factories and in collateral activities, trade and services. But if economic reasons are at the origin of urbanism, in many countries the escape from the countryside is connected to a search for social promotion. The low standard of living and the backward conditions of the rural class have led young people to seek a more guaranteed and more dignified job in the city: mechanization has contributed to this, which has reduced jobs in the agricultural sector.

The urbanism of the underdeveloped countries is more dramatic, where crowds of peasants uprooted from the fields cling to cities unable to absorb them, and cram into peripheral shanty towns (bidonvilles).

The urban population is divided into cities of disparate dimensions: from small towns to provincial cities to regional metropolises. Although the importance of a city cannot be deduced from the number of inhabitants, this still provides an indicative value, on the basis of which it is usual to define as large cities those which have more than 100,000 inhabitants, and as millionaire cities those which exceed one million.

The large metropolises are the mirror of the rapid urbanization process of humanity in our century: currently there are about 240 and they concentrate 780 million people, equal to 14% of humanity.

In the Atlantic megalopolis that goes from Washington to Boston, with 50 million inhabitants, the most significant urban product of the neo-industrial economy has been created, the largest concentration of high-ranking services. The result of the neo-industrial economy consists in a powerful expansion of services; but it is also the witness of the tragedies of the megacities: smog hoods, sudden paralysis of urban life, difficulties in the disposal of waste, social tensions and violent clashes. Delinquency and insecurity grow as urban dimensions grow.

Modern urbanism, which began in Europe with the industrial revolution, passed into the New World following the *European civilization* and then spread to other continents, clogging

people with cities at the expense of the countryside. At the beginning of our century the city population represented 14% of the world population; in half a century the urbanity index rose to 28%.

Today, in the world, the population living in cities above 100,000 inhabitants is around 58%. These cities consume 3% of soil and generate 80% of the world's GDP (*source: UN-Habitat Programme*).

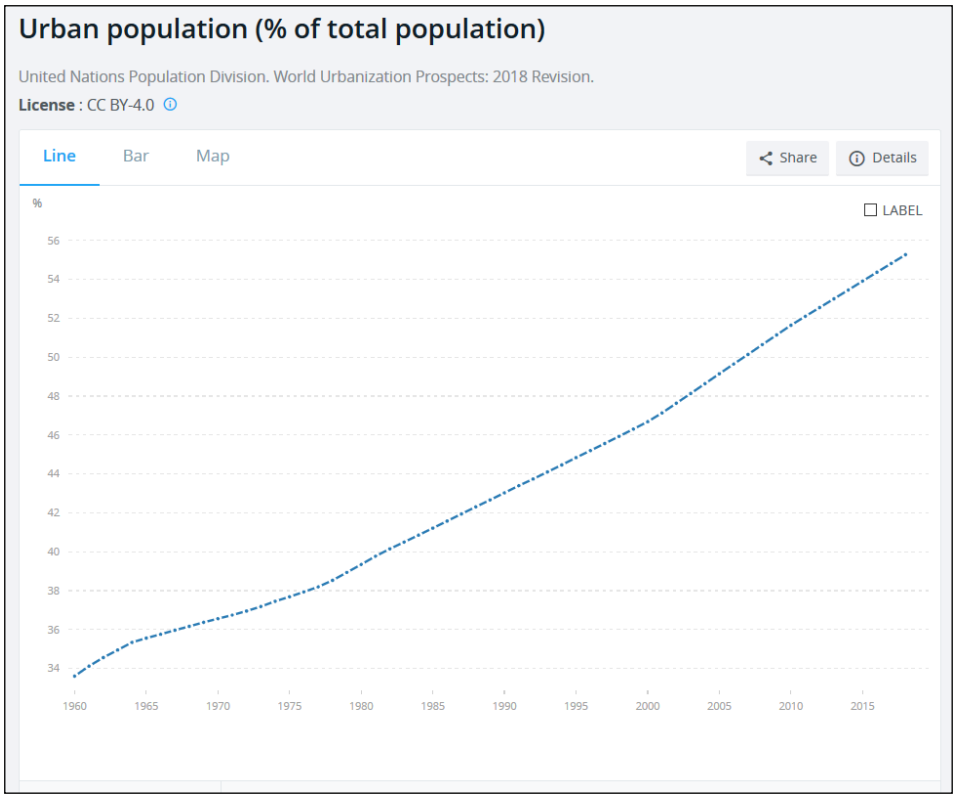


Figure 1 - World Urbanization Prospect (*source: World Bank Open Data*)

In the West the intermediate cities are still growing, while the metropolises have stopped. The phenomenon can be explained in terms of quality of life: the improvement of transport and the spread of services throughout the territory have reduced the advantages of living in the big city, of which the disadvantages are always tolerated, such as the high costs and the congestion.

If in less developed countries the metropolises continue to swell, this is due to the high birth rate, but also to the fact that people find there a job hope and a mirage of life preferable to the countryside.

See for example, being the object of the following analyses, the level of urbanization in Brazil which abundantly exceeds 80%.

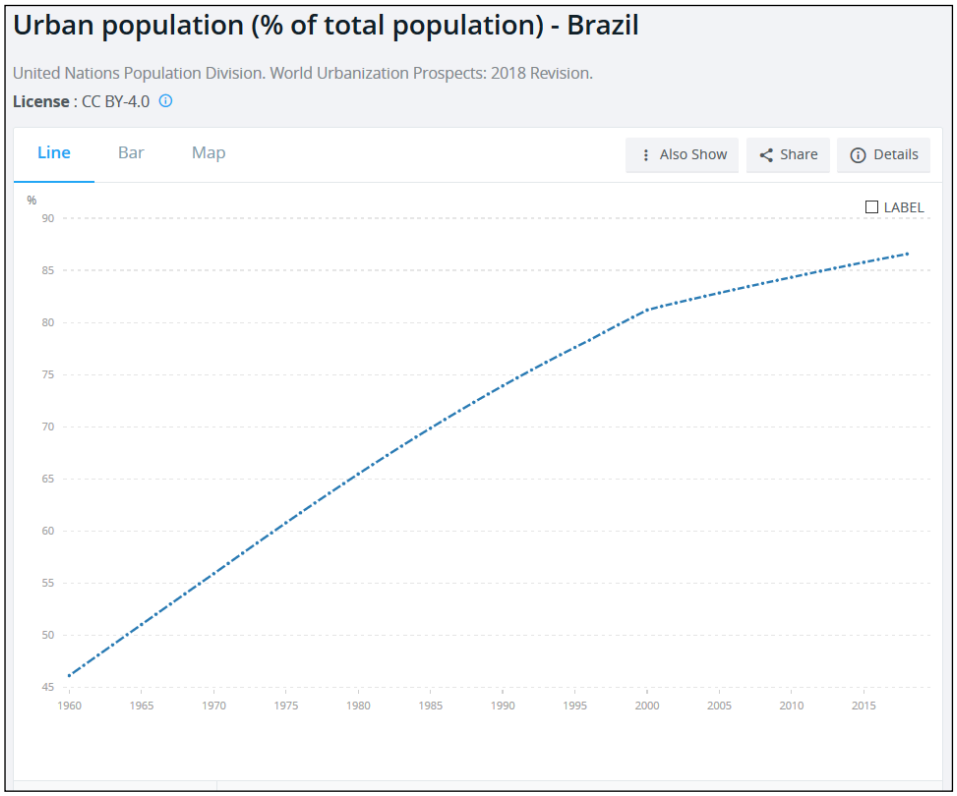


Figure 2 - Brazil Urbanization Prospect (*source: World Bank Open Data*)

On a systematic level, four types of urban concentrations can be identified:

- ***The European type***: is linked to the industrial revolution and the development of international trade.
- ***The new countries type*** (with a European population): these countries have experienced sudden urban growth: urban population rates remain high because extensive agriculture over large areas, managing to produce a lot with a small workforce, attracts few people and gives food surpluses for a large city population.
- ***The Soviet type***: has fairly high but always controlled urban population rates, in harmony with economic development planning.
- ***The underdeveloped countries type***: records a situation in which the city population reaches just a quarter of the total, when it does not stop at even lower values. The accelerated growth produces distortions in favor of a primate city or a few nodal centers, which stand out for their demographic dimensions on all the other centers.

The central role played by the urban phenomenon in the history of civilization is today compromised by excessive and disordered development. The explosion of metropolitan systems risks worsening the situation of humanity because uncontrolled urbanism leads to

unemployment and underemployment, delinquency, marginalization of immigrant groups in the slums, congestion, environmental degradation and pollution.

The 25 most populous urban areas are listed in Figure 3.

City	Official n.	Metropolitan area	Official n. (2)	Reference year
	Inhabitants		Inhabitants	
Tokyo	15.190.000	Grande Area di Tokyo	37.835.000	2014
Shanghai	24.260.000	===	24.260.000	2014
Karachi	24.000.000	===	24.000.000	2013
Città del Messico	8.850.000	Città del Messico	24.000.000	2013
New York	8.500.000	New York metropolitan area	23.000.000	2015
Seul	10.400.000	Seul	22.700.000	2000
Pechino	21.500.000	===	21.500.000	2014
Mumbai (Bombay)	12.500.000	Mumbai (Bombay)	21.000.000	2011
Delhi	16.300.000	Delhi	20.000.000	2014
San Paolo	11.320.000	Regione metropolitana di San Paolo	20.000.000	2010
Mosca	12.300.000	Mosca	18.000.000	2016
Osaka	2.700.000	Keihanshin	18.000.000	2014
Lagos	16.300.000	===	16.300.000	2015
Il Cairo	10.000.000	Il Cairo	15.200.000	2014
Bangkok	7.025.000	Bangkok	15.000.000	2009
Istanbul	15.000.000	===	15.000.000	2014
Calcutta	4.490.000	Calcutta	14.100.000	2011
Londra	8.600.000	London metropolitan area	14.000.000	2015
Buenos Aires	2.900.000	Buenos Aires	13.500.000	2010
Teheran	8.300.000	Teheran	13.500.000	2008
Parigi	2.240.000	Grand Paris	12.100.000	2014
Los Angeles	4.050.000	Los Angeles area	12.000.000	2016
Rio de Janeiro	6.320.000	Regione metropolitana di Rio	11.000.000	2010
Giacarta	10.075.000	===	10.075.000	2014
Washington	672.000	Washington-Baltimora	8.500.000	2010

Figure 3 - The 25 most populous urban areas in the world (*source: UN-Habitat Programme*)

From these simple data we understand how cities must be rethought both in terms of sustainability and liveability. We begin to glimpse the need for a Smart City concept that marries a *New Humanism*.

Having taken note of these migrations of peoples to the cities, the challenge of our century will be the construction of a new kind of common good, a large technological and immaterial infrastructure that makes people and objects dialogue, integrating information and generating intelligence, producing inclusion and improving our daily life.

1.2 The evolution of the Smart City concept

From the previous paragraph it is clear both the problem to be solved and the final objective.

However, it must be recognized that this point of arrival was an evolution of thoughts generated by different stimuli.

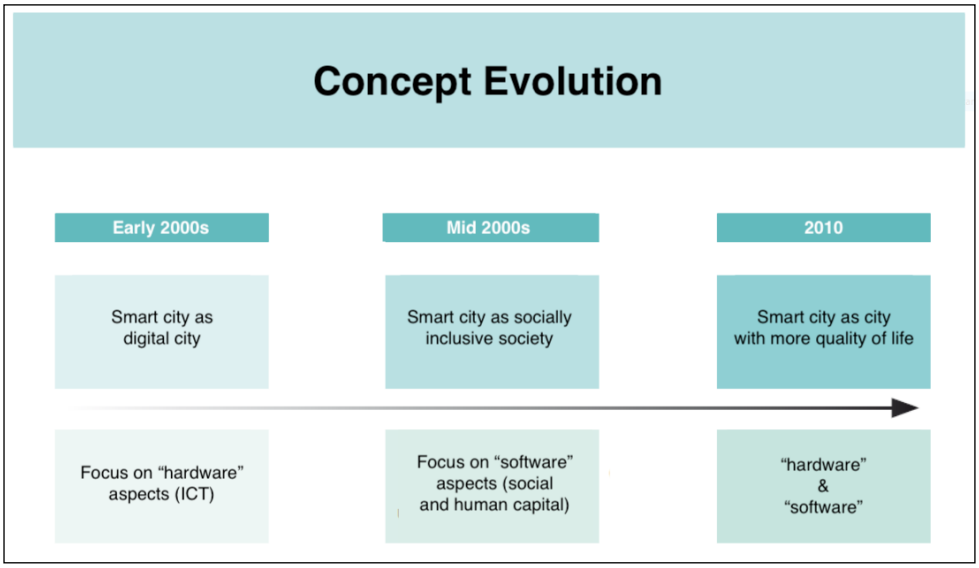


Figure 4 - The evolution of Smart City concept

The first studies concerning Smart Cities date back to the nineties, in fact, these researches are in a period of liberalization of telecommunications, also thanks to the rise of Internet services, in which the same technologists and marketers put their attention on 'topic.

At the turn of the millennium, two well-known multinationals such as IBM and CISCO had elaborated the vision of an ideal city with a strong automation content, which saw the ICT infrastructures as the key of urban intelligence. Over time, the expression Smart City had therefore become synonymous with a city characterized by the intelligent and extensive use of digital technologies.

Consequently, on the one hand we had a clear idea of SC as the only promising path towards an all-encompassing progress (see paragraph on Urbanism), on the other hand the operators who disagreed on the determining factors acting consequently in a confusing way.

Effectively, the appellation Smart identifies as a digital city, both the socially inclusive city and the city that ensures a better quality of life, taking advantage of the opportunities and knowledge that come from the world of research and technological innovation.

It follows that the concept of smartness based only on technology level is wrong, also needing that concrete aspects emerge on human, social, relational and environmental capital, as important factors of urban growth.

Author	Year	Definition
R. Hall	2000	"*A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximising services to its citizens*".
Partridge	2004	"A city where the ICT strenghten the freedom of speech and the accessibility to public information and services".
Giffinger	2007	"A city well performing in a forward-looking way in economy, people, governance, mobility, environment and living, built on the smart combination of endowments and activities of self-decisive, indipendent and aware citizens".
Rio	2008	"A city that gives inspiration, shares culture, knowledge, and life, a city that motivates its inhabitants to create and flourish in their own lives".
Nam & Pardo	2009	"According to the literature, it is possible to define a set of fundamental factors which make a city smart: technology, people and institution. Given the connection between the factors, a city is smart when investments in human/social capital and IT infrastructure fuel sustainable growth and ehance a quality of life, through participatory governance".
Kanter & Litow	2009	"A smart city should be viewed as an organic whole -as a network, as a linked system. In a smarter city, attention is paid to the connections and not just to the parts".
Washburn	2010	"The use of Smart Computing technologies to make the critical infrastructure components and services of a city -wich include city administration, eaducation, healthcare, public safety, real estate, transportation, and utilities- more intelligent, interconnected, and efficient".
IBM	2010	"An instrumented, interconnected, and intelligent city. Instrumentation enables the capture and integration of live real-world data through the use of sensors, kiosks, meters, personal devices, appliances, cameras, smart phones, implanted medical devices, the web, and other similar data-acquisition systems, including social networks as networks of human sensors. Interconnected means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligent refers to the inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions".
Papa, Gargiulo et al	2013	"A smart city is not just about using less energy or being made of smart and reusable materials. It is about being able to function as an integral part of a largeer system, that also regards participation, human capital, education and learning in urban development".

Figure 5 - Evolution of the Definition of Smart City over time

This statement claims the fact that a smart city needs that these elements are not independent from each other, but that they embrace the entire social dimension and that they are within an overall and systematic vision of the city and its future. Otherwise, only fragments would remain, pieces of a mosaic whose design cannot be read. A city can be defined as smart when investments in human and social capital and in traditional (transport) and modern (ICT) infrastructures fuel sustainable economic development and a high quality of life, with wise management of natural resources, through a participatory governance method .

In Figure 5, some definitions of SC and their evolution over time have been collected.

As you can see by reading carefully the definition of Hall (2000), you start by thinking of a 'Hardware' city capable of monitoring all its infrastructures (railways, roads, bridges, water, electricity, etc.), predicting any malfunctions, optimizing their management ensuring the security and maximization of services to citizens.

On the opposite side, at the end of this time excursus, we have the idea of Pope, Gargiulo et al. (2013) that come to the definition of SC as an integral part of a wider system that takes

into account not only technological aspects, but mainly concerns participation, human capital, education and teaching within an urban development sustainable.

In just one decade, we have gone from a vision of a *technological city* to a vision of a *human city*.

1.3 Measurement of living conditions in cities

The aforementioned 'humanity', to which cities must strive, involves various aspects. In particular, several consultancy companies have ventured into measuring abstract parameters such as 'liveability', 'attractiveness' and 'green sustainability'.

These rankings, evaluating various aspects that, with different weights, help to create the overall index allow you to compare different cities widespread all over the world.

Given the global coverage of these works, we will try to use them to compare the European reality with the Brazilian one in order to contextualize a starting and comparison point between Brazil and Europe.

The relative reports typically have an annual frequency and thus make it possible to follow the evolution of many metropolises. Reading these documents, attention can be focused on specific details concerning 'humanity' that these metropolises can offer to their citizens and how this abstract concept has evolved over time.

Several consultancy firms have developed these indicators. Below are the most famous indices trying to provide a global vision from important consulting firms distributed all over the world.

In particular, the reports of:

- Economist Intelligence Unit – England;
- Mercer – Canada;
- Mori Memorial Foundation– Japan;
- AT Kearney - US.

One of the bodies that worked a lot on these measurements was the Economist Intelligence Unit (EIU).

The *Economist Intelligence Unit (EIU)* is a British business unit within the Economist Group providing forecasting and advisory services through research and analysis, such as monthly country reports, five-year country economic forecasts, country risk service reports, and industry reports.

It has defined three indexes:

1. ***Global Liveability Index*** focused on measuring the living conditions in cities, analysing these latter on the basis of five quantities, allowing the creation of a new model.

The categories on which it is based are:

- Stability;
- Healthcare;
- Culture & Environment;
- Education;
- Infrastructure.

2. ***Global City Competitiveness Index*** which allows the measurement of the degree of competitiveness of cities. This index was created to measure the attractiveness of capital, businesses, talents and visitors, based on eight dimensions here:
    - Economic stability;
    - Human capital;
    - The effectiveness of the institutions;
    - Financial maturity;
    - The global appeal;
    - Physical capital;
    - The environment and natural risks;
    - Social and cultural characteristics.
3. ***Green City Index*** which measures the environmental sustainability of the world's major cities, also based on eight dimensions:
    - Average CO_2 emission;
    - Availability of energy;
    - Efficiency of the buildings;
    - Effectiveness of transport;
    - Waste disposal land use;
    - Use of water;
    - Air quality;
    - Environmental governance.

Another indicator that analyse the quality of life on a periodic basis has been developed, on an annual basis, by the Canadian consultancy firm Mercer.

Mercer is a global leader in consultancy and technological solutions for the development and organization of Human Capital, for actuarial services, social security and for investments by institutional investors.

4. ***Mercer Quality of Living Index*** measures the quality of life considering 10 dimensions related to:
    - Consumer goods;
    - Economic environment;
    - Housing;

- Medical and health considerations;
- Natural environment;
- Political and social environment;
- Public services and transport;
- Recreation;
- Schools and education;
- Socio-cultural environment.

In 2008, the *Mori Memorial Foundation*, a Japanese foundation specialized in research on strategies for urban development, developed an index thanks to which it is possible to measure the degree of urban competitiveness.

5. ***Global Power City Index*** measures the level of attractiveness of human capital and companies, on the basis of six dimensions that are divided into sixty-nine indicators. The dimensions identified are intended to identify the attractive forces of human capital and businesses in a context of maximum competition for cities. In detail, the dimensions analysed are:
    - Economy;
    - Research & Development (R&D);
    - Cultural Interaction;
    - Liveability;
    - Environment;
    - Accessibility.

AT Kearney is a US multinational strategic consulting firm. It specializes in sectors such as aerospace and defence, automotive, chemical, media and telecommunications, consumer and retail products, financial institutions, healthcare, metals and mines, oil and gas, private equity, public sector, transport, infrastructure and public services.

6. ***Global Cities Index*** measures the level of insertion in the global context of cities. Measurement is based on five factors:
    - Business activity;
    - Human capital;
    - Exchange of information;
    - Culture;
    - Political participation.

There are also other indicators which, although they may be considered interesting, have not found the same attention as those previously examined:

7. ***City of Opportunity*** examines cities looking at social and economic aspects.
8. ***Innovation City Index*** analyses the economic innovation of cities by formulating periodic rankings since 2007.

9. ***Global ranking of top 10 resilient cities*** it measures how cities work to mitigate the effects of climate change and to adopt energy sustainability solutions.
10. ***Open City Monitor*** analyses openness, understood as the ability of a city to attract people capable of contributing to the future success of the city.
11. ***Most Liveable Cities Index*** published annually since 2007 by the Monocle magazine, which analyses the level of a city through various indicators including urban development and urban design.

All the indicators listed are just some examples of the many attempts to measure the quality of life in our cities.

An attempt was made to recover the reports relating to the most important ones in order to deepen the applied methodology and results. Below we have reported what we found. It should be noted that the reports are not homogeneous by measurement period but in any case, give an interesting idea on how the cities and geographical areas covered by this thesis work.

1.3.1 Global Liveability Index

As anticipated, this index elaborated by EIU is evaluated on 5 categories through appropriate percentage weights. In turn the various categories are in total a further 30 subfields.

In Figure 6, the diagram that defines how the index is composed, the weight given to the individual categories, the subcategories and the origin of the data:

Category 1: Stability (weight: 25% of total)

Indicator	Source
Prevalence of petty crime	EIU rating
Prevalence of violent crime	EIU rating
Threat of terror	EIU rating
Threat of military conflict	EIU rating
Threat of civil unrest/conflict	EIU rating

Category 2: Healthcare (weight: 20% of total)

Indicator	Source
Availability of private healthcare	EIU rating
Quality of private healthcare	EIU rating
Availability of public healthcare	EIU rating
Quality of public healthcare	EIU rating
Availability of over-the-counter drugs	EIU rating
General healthcare indicators	Adapted from World Bank

Category 3: Culture & Environment (weight: 25% of total)

Indicator	Source
Humidity/temperature rating	Adapted from average weather conditions
Discomfort of climate to travellers	EIU rating
Level of corruption	Adapted from Transparency International
Social or religious restrictions	EIU rating
Level of censorship	EIU rating
Sporting availability	EIU field rating of 3 sport indicators
Cultural availability	EIU field rating of 4 cultural indicators
Food & drink	EIU field rating of 4 cultural indicators
Consumer goods & services	EIU rating of product availability

Category 4: Education (weight: 10% of total)

Indicator	Source
Availability of private education	EIU rating
Quality of private education	EIU rating
Public education indicators	Adapted from World Bank

Category 5: Infrastructure (weight: 20% of total)

Indicator	Source
Quality of road network	EIU rating
Quality of public transport	EIU rating
Quality of international links	EIU rating
Availability of good quality housing	EIU rating
Quality of energy provision	EIU rating
Quality of water provision	EIU rating
Quality of telecommunications	EIU rating

Figure 6 - Global Liveability Index Categories and Composition, 2019 (*source: EIU*)

Let's now understand how this ranking works and what its purpose is.

"The concept of liveability is simple: it assesses which locations around the world provide the best or the worst living conditions. Assessing liveability has a broad range of uses, from benchmarking perceptions of development levels to assigning a hardship allowance as part of expatriate relocation packages. Our liveability rating quantifies the challenges that might be presented to an individual's lifestyle in any given location, and allows for direct comparison between locations. Every city is assigned a rating of relative comfort for over 30 qualitative and quantitative factors across five broad categories: stability, healthcare, culture and environment, education, and infrastructure. Each factor in a city is rated as acceptable, tolerable, uncomfortable, undesirable or intolerable. For qualitative indicators, a rating is awarded based on the judgment of in-house analysts and in-city contributors. For quantitative indicators, a rating is calculated based on the relative performance of a number of external data points. The scores are then compiled and weighted to provide a score of 1–100, where 1 is considered intolerable and 100 is considered ideal.

The liveability rating is provided both as an overall score and as a score for each category. To provide points of reference, the score is also given for each category relative to New York and an overall position in the ranking of 140 cities is provided." (*source: EIU*)

In 2019, Vienna, for the seventh consecutive year, confirmed itself in first place on the Global Liveability Index with a score close to the maximum 99.1 / 100.

The ten most liveable cities

Country	City	Rank	Overall Rating (100=ideal)	Stability	Healthcare	Culture & Environment	Education	Infrastructure
Austria	Vienna	1	99.1	100	100	96.3	100	100
Australia	Melbourne	2	98.4	95	100	98.6	100	100
Australia	Sydney	3	98.1	95	100	97.2	100	100
Japan	Osaka	4	97.7	100	100	93.5	100	96.4
Canada	Calgary	5	97.5	100	100	90	100	100
Canada	Vancouver	6	97.3	95	100	100	100	92.9
Canada	Toronto	7	97.2	100	100	97.2	100	89.3
Japan	Tokyo	7	97.2	100	100	94.4	100	92.9
Denmark	Copenhagen	9	96.8	95	95.8	95.4	100	100
Australia	Adelaide	10	96.6	95	100	94.2	100	96.4

Figure 7 - The Ten Most Liveable City - Global Liveability Index, 2019 (*source: EIU*)

To analyse the differences due to geographical location, in Figure 8, the cities have been grouped by continents:

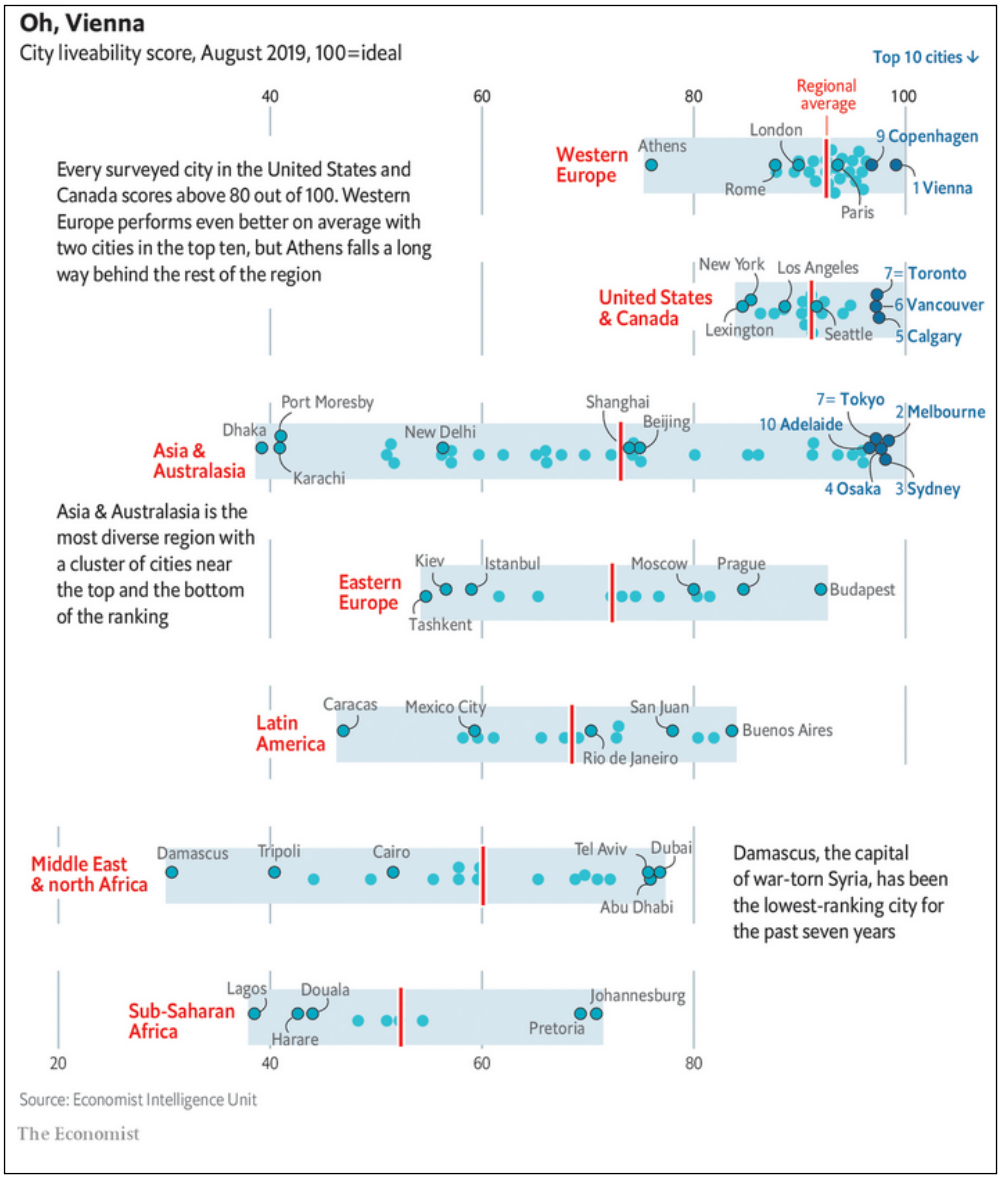


Figure 8 - Global Liveability Score grouped by Geografical Area, 2019 (*source: EIU*)

1.3.2 Global City Competitiveness Index

"Competitiveness is a holistic concept. While economic size and growth are important and necessary, several other factors help determine a city's competitiveness as well, including its business and regulatory environment, the quality of human capital and cultural aspects. These factors not only help a city sustain high economic growth rates, but also create a stable and harmonious business and social environment. Against this backdrop, we define 'competitiveness' as the demonstrated ability to attract capital, businesses, talent and visitors. We assessed 120 cities across the world and examined 31 indicators for each city. Indicators were grouped under eight distinct, thematic categories: economic strength,

human capital, institutional effectiveness, financial maturity, global appeal, physical capital, environment and natural hazards, and social and cultural character. There are 21 qualitative and 10 quantitative indicators. A city's overall ranking in the benchmark Index is a weighted score of the underlying categories." (*source: EIU*)

In Figure 9 and 10, the categories, indicators and their weight in the calculation of the index.

Indicator	Unit	Year	Source	Weight	Description
Economic strength				30.0%	
Nominal GDP (PPP)	US$ billion	2008	EIU analysis	25.0%	Nominal GDP reflecting differences in costs of living
GDP per capita (PPP)	US$	2008	EIU analysis	10.0%	Nominal GDP (PPP) per person.
Households with annual consumption >US$14,000 (PPP)	Percentage	2010	C-GIDD, EIU analysis	10.0%	Proportion of a city's households with annual consumption over US$14,000 (PPP).
City real GDP growth rate	CAGR	2010-2016	C-GIDD, EIU analysis	45.0%	Cumulative average annual growth rate (CAGR).
Regional market integration	EIU rating	2011-2015	EIU analysis	10.0%	5=The country belongs to an economic union. There is freedom of movement for goods, people and capital; 1=Not member of any regional grouping.
Human capital				15.0%	
Population growth	CAGR	2010-2020	World urbanisation prospects 2009, United Nations; Demographia World Urban Areas, 2011; Country statistical agencies; and EIU estimates	12.5%	Cumulative average annual growth of population size.
Working-age population	Percentage of total population	2010	Country statistical offices; EIU analysis	8.3%	Working-age population (15-64 years) as a percentage of the total population.
Entrepreneurship and risk-taking mindset	EIU rating	2010	Eurobarometer survey (2009); World Values Survey; Global Entrepreneurship Monitor 2010; BBC World Service Poll-GlobeScan/PIPA survey; and EIU analysis	25.0%	5=Strong entrepreneurial/risk-taking mindset; 1=Weak entrepreneurial/risk-averse mindset; Ratings are based on fear of failure, entrepreneurship/self-employment as a career choice and entrepreneurial intentions.
Quality of education	EIU rating	2010	EIU analysis	33.3%	5=Highest, 1=Lowest; Availability and quality of private education, and general public education indicators.
Quality of healthcare	EIU rating	2010	EIU analysis	8.3%	5=Highest, 1=Lowest; Availability and quality of public and private healthcare, and availability of over the counter (OTC) drugs.
Hiring of foreign nationals	EIU rating	2011- 2015	EIU analysis	12.5%	5=Very easy; 1=Very difficult. Assessment includes immigration barriers, rules on employment of local nationals and other unofficial barriers.
Institutional effectiveness				15.0%	
Electoral process and pluralism	EIU rating	2010	EIU Democracy Index 2010	14.3%	10=Free and fair electoral process and vibrant pluralism; 1=Limited electoral processes
Local government fiscal autonomy	EIU rating	2010	Global Observatory on Local Democracy and Decentralisation, United Cities and Local Governments	28.6%	1=No fiscal autonomy; 2=Some fiscal discretion, but extensive controls exist; 3=Fair fiscal independence, but some controls exist; 4=Extensive fiscal autonomy.
Taxation	EIU rating	2011	EIU analysis	14.3%	5=Highest, 1=Lowest; Standard VAT rate in the city and the broader complexity of tax regime.
Rule of law	World Bank score	2009	World Bank	14.3%	2.5=Very good; -2.5=Very poor; Assessment of confidence in and abide by rules of society.
Government effectiveness	EIU rating	2010-2011	Transparency International; EIU analysis	28.6%	Based on the level of corruption (10=Least corrupt, 0=Most corrupt) measured by Corruption Perceptions Index 2010, Transparency International, and EIU analysis of effectiveness in policy implementation, and quality of bureaucracy (5=Highest, 1=Lowest).
Financial maturity				10.0%	
Breadth and depth of the financial cluster	EIU rating	2011	Z/Yen Group's Global Financial Centres Report 2011; EIU analysis	100%	7=Established global cluster which is broad and deep; 1=City is lacking even basic financial infrastructure.

Figure 9 - Brief Description of Indicators, Data Sources and Weights (1), 2012 (*source: EIU*)

Indicator	Unit	Year	Source	Weight	Description
Global appeal				10.0%	
Number of Fortune 500 companies	Number	2011	Fortune Magazine	20.0%	Number of world's largest corporations by revenues headquartered in the city.
Frequency of international flights	Flights per week	2011	OAG Aviation	20.0%	Frequency of international flights per week from the city's major airport.
No of international conferences and conventions	Number	2010	International Congress and Convention Association (ICCA)	20.0%	International conferences and seminars must be attended by at least 50 participants; organised on a regular basis (one-time events are not assessed); and move between countries.
Global leadership in higher education	EIU rating	2010	QS World University; Financial Times Global MBA rankings	20.0%	Number of universities, technology and engineering programmes and MBA programmes in the city.
Globally-renowned think-tanks	Number	2009	The Think Tanks and Civil Societies Program, The Global "Go-To Think Tanks", University of Pennsylvania	20.0%	Number of think tanks nominated to the list by a panel of experts and scholars.
Physical capital				10.0%	
Quality of physical infrastructure	EIU rating	2010	EIU analysis	42.9%	5=Highest, 1=Lowest; Based on quality of road network in the city, regional or international links, and access to and quality of seaport.
Quality of public transport	EIU rating	2010	EIU analysis	14.3%	5=Excellent quality, public transport systems suitable for executives to use - regular and efficient; 1=Extremely bad quality, the transport network is largely outdated.
Quality of telecommunications infrastructure	EIU rating	2010	EIU analysis	42.9%	5=Very good, extensive and modern network, very few disruptions, speedy and regular maintenance available; 1=Very poor, inadequate and out of date network, disruptions are common, maintenance extremely poor and very slow.
Environment and natural hazards				5.0%	
Risk of natural disasters	EIU rating	2011	Global Risk Data Platform, United Nations Environment Programme; NATHAN (Natural Hazards Assessment Network) Risk Suite, Munich Re; EIU analysis	33.3%	5=Very high risk; 1=Very low risk; Natural hazard risk assessment includes earthquakes, storm surges, floods, tsunamis, tornadoes and wildfires. The indicator looks at the frequency of past events to ascertain risk level for each city.
Environmental governance	EIU rating	2010	EIU analysis	66.7%	30=Very good, 0=Very poor; Assessment of city's government's commitment towards monitoring and standards of water, waste and air.
Social and cultural character				5.0%	
Freedom of expression and human rights	Rating	2011	Freedom House	20.0%	10=Highest, 1=Lowest. Examines freedom of expression and belief, associational and organisational rights, rule of law, personal autonomy, and individual rights.
Openness and diversity	EIU rating	2010	EIU analysis	20.0%	5=Very open and diverse; 1=Very closed and homogenous. Assessment of ethnic diversity, variety of languages spoken, ubiquity of English language use and general acceptance of different lifestyles.
Presence of crime in the society	EIU rating	2010	EIU analysis	20.0%	10=Highest, 0=Lowest; Presence of petty and violent crime in city.
Cultural vibrancy	EIU rating	2010	EIU Liveability Survey; EIU analysis	40.0%	5=Highest, 1=Lowest; Cultural vibrancy considers availability of quality restaurants, presence of a world-known cuisine, quality theatre production, classical and modern music concerts, presence of a one or more UNESCO heritage site and presence of one of more international book fairs.

Figure 10 - Brief Description of Indicators, Data Sources and Weights (2), 2012 (*source: EIU*)

Below are the scores reported in 2012 by the 120 cities sampled divided by region.

Rank	Country	Score
Africa		
1	Johannesburg	47.1
2	Cape Town	45.9
3	Durban	41.2
4	Cairo	35.0
5	Nairobi	34.6
6	Alexandria	31.8
7	Lagos	27.6
Asia Pacific		
1	Singapore	70.0
2	Hong Kong	69.3
3	Tokyo	68.0
4	Sydney	63.1
5	Melbourne	62.7
6	Seoul	60.5
7	Auckland	56.7
8	Taipei	56.6
9	Beijing	56.0
10	Shanghai	55.2
11	Kuala Lumpur	55.0
12	Osaka	52.9
13	Nagoya	52.3
14	Shenzhen	51.7
15	Incheon	50.2
16	Bangkok	49.0
17	Fukuoka	47.7
=18	Guangzhou	47.4
=18	Busan	47.4
20	Delhi	46.7
21	Mumbai	46.6
22	Tianjin	45.4
23	Bangalore	44.6
24	Jakarta	44.1
25	Dalian	44.0
26	Chengdu	43.5
27	Suzhou (Jiangsu)	43.4
28	Manila	43.2
29	Chongqing	42.9
30	Qingdao	42.1
31	Ahmedabad	41.9
32	Hangzhou	41.6
33	Pune	39.8
34	Hyderabad	39.4
35	Almaty	39.3
36	Hanoi	38.8
37	Chennai	38.1
38	Kolkata	37.8
39	Ho Chi Minh City	36.5
40	Surabaya	35.9
41	Colombo	35.6
42	Karachi	35.5
43	Bandung	34.8
44	Dhaka	27.7

Rank	Country	Score
Europe		
1	London	70.4
2	Paris	69.3
3	Zurich	66.8
4	Frankfurt	64.1
5	Geneva	63.3
6	Amsterdam	62.4
7	Stockholm	60.5
8	Copenhagen	59.9
9	Vienna	59.8
10	Dublin	59.5
11	Madrid	59.4
12	Berlin	58.2
13	Oslo	57.2
14	Brussels	57.1
15	Hamburg	56.8
16	Birmingham	56.6
17	Barcelona	55.8
18	Prague	53.7
19	Milan	52.9
20	Rome	52.3
21	Warsaw	51.3
22	Monaco	51.0
23	Budapest	50.4
24	Lisbon	49.5
25	Moscow	49.4
26	Kraków	47.3
27	Athens	46.1
28	Istanbul	45.5
29	Bucharest	44.9
30	Ankara	40.9
31	Saint Petersburg	39.3
32	Kiev	36.8
Middle East		
1	Dubai	55.9
2	Abu Dhabi	55.8
3	Doha	52.9
4	Tel Aviv	49.3
5	Kuwait City	44.2
6	Muscat	43.0
7	Riyadh	37.8
8	Beirut	30.6
9	Tehran	27.2
North America		
1	New York	71.4
2	Washington	66.1
3	Chicago	65.9
4	Boston	64.5
5	Toronto	63.9
6	San Francisco	63.3
7	Vancouver	61.8
8	Los Angeles	61.5
9	Montréal	60.3
10	Houston	59.9
11	Dallas	59.8
12	Seattle	59.3
13	Philadelphia	58.5
14	Atlanta	58.2
15	Miami	55.2

Figure 11 - Global City Competitiveness Score by Region (1), 2012 (*source: EIU*)

Rank	Country	Score
South and Central America		
1	Buenos Aires	49.2
2	São Paulo	48.3
3	Santiago	46.7
4	Mexico City	46.2
5	Rio de Janeiro	44.9
6	Panama City	44.8
7	Lima	42.5
8	Bogotá	42.3
9	Monterrey	42.2
10	Medellín	40.0
11	Belo Horizonte	39.4
=12	Porto Alegre	39.0
=12	Guadalajara	39.0

Figure 12 - Global City Competitiveness Score by Region (2), 2012 (*source: EIU*)

1.3.3 Green City Index

The Green City Index 2012 report produced by EIU in collaboration with Siemens is not unique, but multiple reports have been produced for the various geographical areas. This is due to the difficulty of comparing the data collected due to their non-homogeneity.

A summary was produced in which the rankings by geographical area are reported.

The rankings are given numerically for the cities of Europe, US and Canada and instead using five 'bands' ranging from 'well above average' to 'well below average' for areas where the validity and comparability of the data in particular, Asia, Latin America and Africa were not guaranteed.

"The Green City Index methodology was developed by the Economist Intelligence Unit (EIU) in cooperation with Siemens. Cities were selected for their size and importance (mainly capital cities and large population or business centres). They were picked independently, rather than relying on requests from city governments to be included or excluded, in order to enhance each Index's credibility and comparability. The Green City Index series measures cities on approximately 30 indicators across eight to nine categories depending on the region. It covers CO2 emissions, energy, buildings, land use, transport, water and sanitation, waste management, air quality and environmental governance. About half of the indicators in each Index are quantitative – usually data from official public sources, for example, CO2 emissions per capita, water consumption per capita, recycling rates and air pollutant concentrations. The remainder are qualitative assessments of the city's environmental policies – for example, the city's commitment to sourcing more renewable energy, traffic-congestion-reduction policies and air quality codes. Measuring quantitative and qualitative indicators together means the Indexes are based on current environmental performance as well as the city's intentions to become greener. The specific indicators differ slightly from Index to Index, taking into account data availability and the unique challenges in each

region. For example, the African Index includes indicators measuring access to electricity and potable water, and the percentage of people living in informal settlements. Each city receives an overall Index ranking and a separate ranking for each individual category. The results are presented numerically (for the European, and the US and Canada Indexes) or in five performance bands from "well above average" to "well below average" (for the Asian, Latin American and African Indexes). Bandings are used in regions where levels of data quality and comparability do not allow for a detailed numerical ranking." (*source: EIU*)

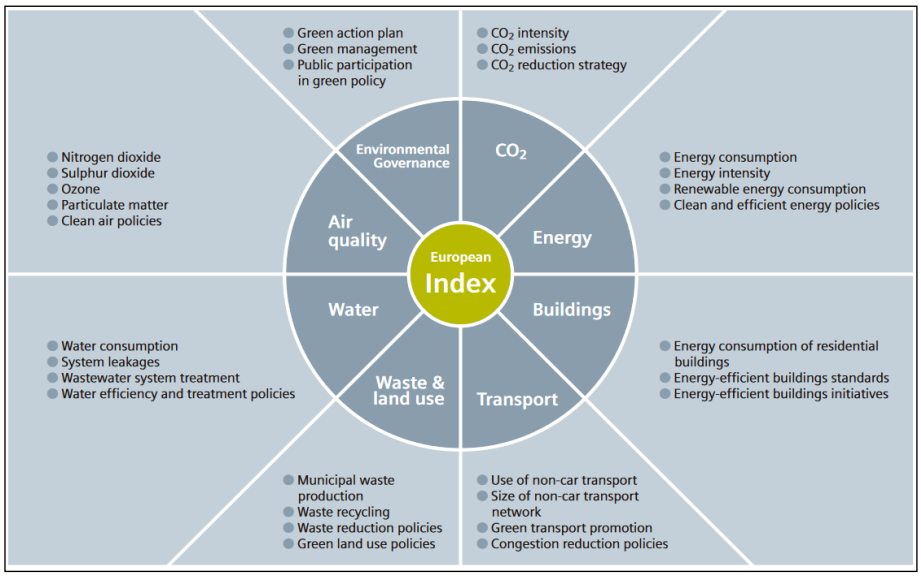
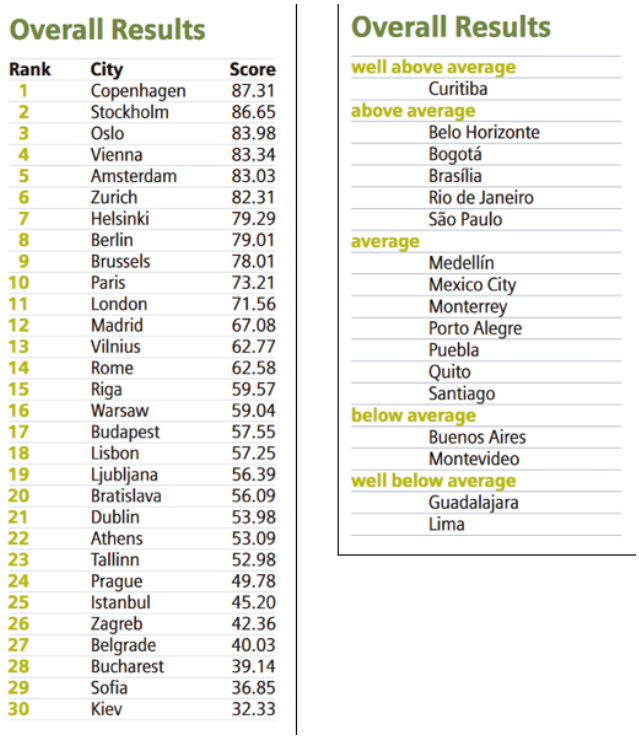


Figure 13 - Green City Index Categories

The *Latin American Green City Index, 2012* analyses the 17 cities listed below.

Figure 14 - Analysed Cities in 2012 Latin America Green City Index, (*source: EIU*)

Although not comparable, we report below, for completeness of information, the numerical ranking of the sampled European cities and the band ranking of those of Latin America.



Overall Results

Rank	City	Score
1	Copenhagen	87.31
2	Stockholm	86.65
3	Oslo	83.98
4	Vienna	83.34
5	Amsterdam	83.03
6	Zurich	82.31
7	Helsinki	79.29
8	Berlin	79.01
9	Brussels	78.01
10	Paris	73.21
11	London	71.56
12	Madrid	67.08
13	Vilnius	62.77
14	Rome	62.58
15	Riga	59.57
16	Warsaw	59.04
17	Budapest	57.55
18	Lisbon	57.25
19	Ljubljana	56.39
20	Bratislava	56.09
21	Dublin	53.98
22	Athens	53.09
23	Tallinn	52.98
24	Prague	49.78
25	Istanbul	45.20
26	Zagreb	42.36
27	Belgrade	40.03
28	Bucharest	39.14
29	Sofia	36.85
30	Kiev	32.33

Overall Results

well above average	
	Curitiba
above average	
	Belo Horizonte
	Bogotá
	Brasília
	Rio de Janeiro
	São Paulo
average	
	Medellín
	Mexico City
	Monterrey
	Porto Alegre
	Puebla
	Quito
	Santiago
below average	
	Buenos Aires
	Montevideo
well below average	
	Guadalajara
	Lima

Figure 15 - Numerical ranking of the sampled European cities and Band ranking of those of Latin America, (*source: EIU*)

Chapter 2
The social context in South America and Brazil

As it has been possible to verify, with all the limits due to the availability of the above-mentioned reports, the cities of South America are on average in the lower half of the various rankings. They are superior only to some cities in the Middle East and Africa.

Focusing on the main Brazilian cities covered by this thesis, we will try to contextually socially contextualize the status of some categories listed in the indices described above.

The rural environmental challenges of Latin America, such as Amazonian deforestation, often receive the greatest attention from media, environmentalists and other observers around the world. Although these problems are certainly vital, urban environmental concerns such as traffic congestion, land use policies, waste disposal and air quality are more immediate for most Latin American residents, simply because 81% of the population already lives in cities.

According to the United Nations population division, Latin America is the most urbanized region in developing countries. It is already more urbanized than some parts of the developed world and the percentage of the population living in Latin American cities is expected to increase further. By 2030, the figure will reach 86%, on par with Western Europe. The rapid increase in urban populations has had economic, political and social implications and environmental considerations are the main part of this integrated puzzle. For example, urban sprawl has exerted enormous pressure on existing infrastructure, with implications for buildings, public transport, road networks, quality and access to water, waste collection and sanitation. In the meantime, the path of least resistance for development has often been along existing highways, which encourages residents to use private cars and contributes to the deterioration of air quality. Environmental governance has also been affected, as growing cities now straddle multiple municipal jurisdictions.

Despite what has been said, there are cities of excellence such as Curitiba in Brazil which is the first among the 17 sampled cities of South America in the Green City Index.

In fact, Curitiba, always a pioneer of sustainability in the region, is the undisputed leader of the index. It is the birthplace of the *rapid transit bus* (BRT) and the first major pedestrian street in Brazil. Curitiba is the only city in the index to rank well above the overall average. It is the first alone in two categories, air quality and waste, and is always above average in the other five. Environmental control is also consistently strong and has, with few exceptions, the best policies in each category.

Since 2009, for example, the city's environmental authority has conducted a study on the rate of CO2 absorption in Curitiba's green spaces, as well as assessing total emissions in the city. It is working to move those who live in degraded settlements into low-cost housing where sanitation, waste collection, and water are easier to provide. Despite this, the company that manages the water service in Curitiba has extended the water services and sewage connections to all 1,790 families in the informal settlement, Vila Zumbi dos Palmares, which is located along the banks of one of the main sources of city water.

The main reason for Curitiba's exceptional performance is that it has long been taking a holistic approach to the environment, which, as shown by the Index, is unusual in the rest of the region.

Already in the 1960s, in the face of rapid population growth, municipal officials had implemented proposals to reduce urban sprawl, create pedestrian areas and provide effective and low-cost rapid transit (BRT Bus Rapid Transit). Since then the BRT has become a model for a number of Latin American cities.

In the 1980s, urban planning had foreseen and stimulated integrated initiatives that addressed issues such as the creation of green areas, recycling, waste management and sanitation. This integrated planning has enabled good performance in an environmental area by infecting and creating benefits in others: part of the reason why Curitiba's position in air quality is well above average is the success of public transport and its performance in each category they are linked to the aforementioned holistic approach.

The city's strategy has received praise from experts, including Nicholas You, an urban environmental specialist, who mentioned the example of Curitiba when talking about the obstacles to be overcome in order to obtain concrete results in terms of environmental policies:

"There are several obstacles, including short-term policy versus long-term planning, decentralization, lack of accountability from local authorities and overlapping jurisdictions. But there is a key problem: who is responsible for doing what? This is a pervasive problem in much of the world. Everyone is responsible for part of the problem - such as water, energy and transport, but nobody controls the big picture. Service providers work in splendid isolation, which is contrary to the holistic approach required to make our cities more

sustainable. Curitiba for example is a city that for decades has been doing what all cities should do: long-term top-down urban planning."

This holistic approach meant that all environmental issues became part of the citizens, as well as in European cities such as Copenhagen or Stockholm, to the point that the political class cannot react only when an environmental crisis occurs but must always look to the future.

Below are the classifications by categories of the Green City Index of South America from which you can see the performance of the Brazilian cities and Curitiba.

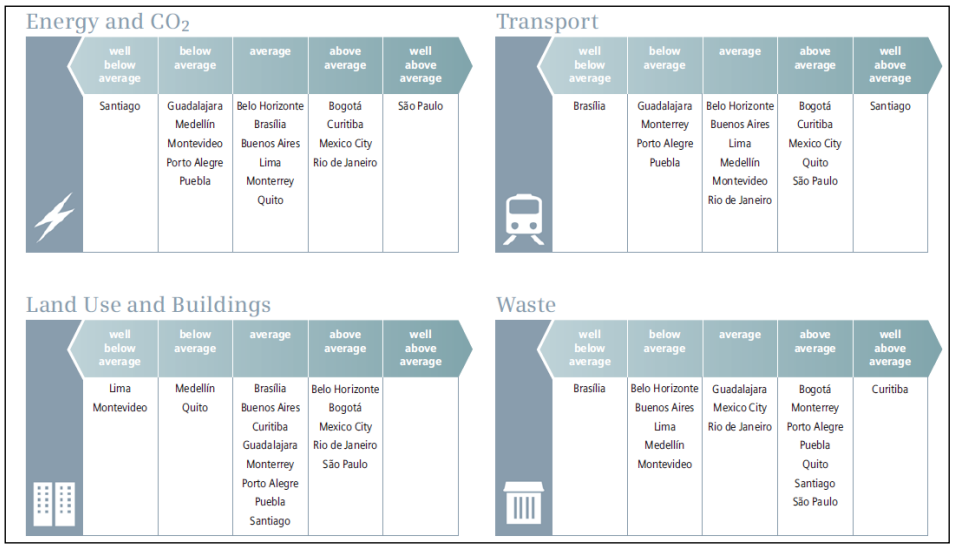


Figure 16 - South America Green City Index per Category (1)

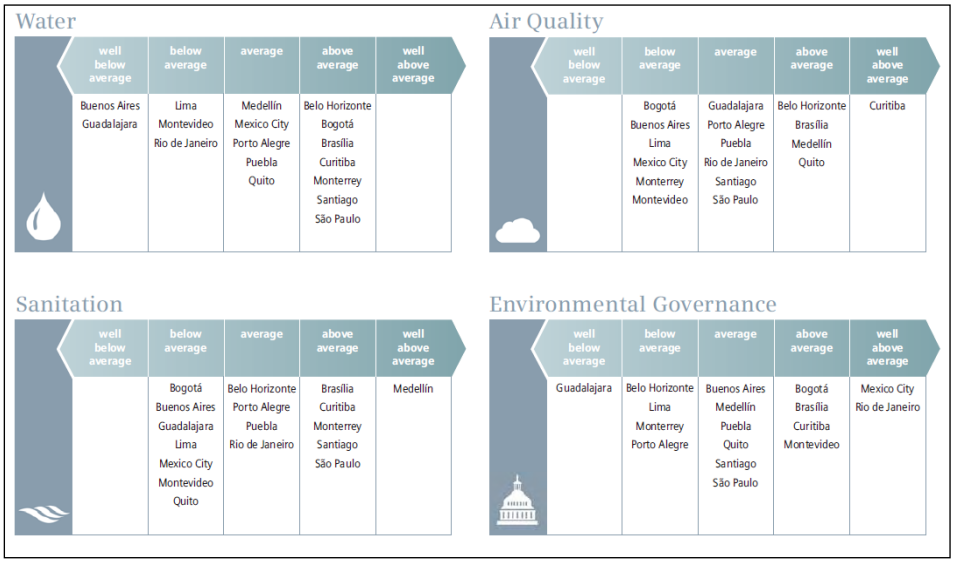


Figure 17 - South America Green City Index per Category (2)

Some Brazilian cities and in particular the best Curitiba, one above the average São Paulo and one in the average Porto Alegre, will be analysed starting from the data of the above report.

2.1 The case of Curitiba

Here below is presented an excerpt from the *Latin American Green City Index (pag. 48-51), 2012* by *The Economist Intelligent Unit*, that refers to the city of Curitiba.

"Curitiba is the capital of the Brazilian state of Paraná, located in the fertile southern region of the country. Although 3.5 million people reside in the metropolitan area, only 1.9 million live within the city limits of Curitiba. Its economy, Brazil's fourth largest, is mainly driven by trade and services, but industry accounts for about a third of its GDP.

The city is also home to many famous national and international companies. Curitiba boasts a GDP per person of $ 10,800. It is considered the best green city among the main cities in Brazil and has gained international recognition for its efforts in sustainable development.

It continues to live up to its reputation in terms of sustainable urban planning with exceptional performances in the various liveability indices. It is the only city that reaches an overall level well above the average, making it the greenest city on the Green Index. Curitiba has excellent performances in the waste and air quality sector, it is the only city to achieve results well above the average in these categories.

Its positioning is supported by progressive policies both in waste management and in clean air. In most other categories Curitiba ranks among the best, always ranking above the average. The worst performance is in the area of land use and buildings, where it is in the average.

Curitiba's extraordinary performance is largely attributable to its global policies. The city is among the best performing for its integrated policies in almost all categories, with some notable exceptions. Curitiba remains at the top of the index even if measured compared to cities with similar incomes and populations.

Energy and CO2

Curitiba is above average in terms of energy and CO2. The city emits far less CO2 from electricity than the index average, with an estimate of 70 kg of CO2 per person compared to the average of 17 cities of 292 kg. The city consumes 743 megajoules of electricity per 1,000 US dollars, which is slightly lower than the average of 761 megajoules.

Curitiba has a good reputation in trying to reduce energy loss in transmission and consume energy more efficiently, and makes at least partial efforts to convert waste by-products into energy. And although the city achieves good results for its energy strategy and

investments in renewable energy (the city produces 84% of its electricity from hydropower) it is marked for not having monitored greenhouse gas emissions and publishing the results.

It is noteworthy that since 2009 the city's environmental authority has conducted an ongoing study on the rate of CO2 absorption in Curitiba's green spaces, as well as on the assessment of total CO2 emissions in the city. Curitiba officials say the results will help them develop plans to neutralize emissions. The city is also changing all street lamps from incandescent lamps to energy saving LED lamps. He announced his intention to replace all diesel used in public transport with low-emission ecological biofuels, the timing of intervention is unclear.

Land use and building

Curitiba is positioned in the average for land use and buildings and is its lowest position in the 'Green' index. Being a city with a low population and one of the smallest administrative areas, Curitiba has a population density of 4,300 people per square kilometre, which is mid-range and stands just slightly below the average of the South American cities analysed. The city could improve its performance in this category by increasing its green spaces. With 52 square meters per person, Curitiba is only average. However, Curitiba receives the best scores for the protection of green spaces that it owns and for its global plan to contain urban sprawl. However, the city is not a good interpreter of eco-building policies, since it has not adopted eco-efficient standards for buildings, nor does it offer incentives to businesses and families to reduce their energy consumption.

Curitiba participates in the Federal Government of Brazil's "My House, My Life" program to provide low-cost housing for people living in informal settlements. The municipal administration says it intends to move approximately 18,000 families living in informal settlements along the banks of the Curitiba's River to permanent housing. This project aims to improve living standards and protect the most vulnerable ecological areas of the city.

In 2007 Curitiba launched a program to incentivize landowners to create public parks on their private land. Landowners who create parks are exempt from local and federal taxes on urban lands. The city says the program is helping to preserve green areas and limit urban sprawl.

Transport

Curitiba ranks above average in transport. Over the last three decades, Curitiba has based its mass transport system on bus "axes", which are dedicated corridors where only buses operate, also known as "bus rapid transit" (BRT).

The city has six such axes carrying 710,000 daily commuters. The transit system is integrated, with commuters able to pay one fare and transfer between different bus lines. Curitiba's investment in buses has helped give it the second longest mass transport network in the Green Index, at an estimated 8.5 km per square kilometre, well above the average of 5 km per square kilometre. At the same time, the city scores well for its urban mass transport policy. Curitiba is taking steps to reduce emissions from urban mass transport, through the replacement of diesel-powered buses with ones running on biofuels.

Despite its well-developed public transport system, Curitiba is marked down for its stock of cars and motorcycles. The city has 0.50 vehicles per person, the second highest rate in the Index and well above the average of 0.30 cars per person. However, the city is proactively tackling its traffic problems, and earns top place for its congestion reduction policies.

Curitiba uses a combination of traffic light sequencing, traffic information systems, dedicated delivery times and access points around the city in order to reduce congestion.

In 2007 Curitiba started rehabilitating the Green Line, a stretch of federal highway that links eastern and western Curitiba. The Green Line now has four exclusive bus lanes and three lanes for private vehicles in each direction. The aim is to cut commuting times, link opposite sides of the city and the neighbourhoods in between, and encourage the use of public transport by cutting bus travel times. Furthermore, six of the 12 buses running on the line operate on soybean-derived biofuel. Officials are closely monitoring their performance, and eventually the city wants all of its buses to run on biofuels. The city is also establishing a public private partnership to build the city's first metro.

Waste

Curitiba is the only city in the Index to achieve a well above average ranking in the waste category. In 1988 it became the first of six Brazilian cities to shut down its open rubbish dump, and instead dispose of all waste in a managed landfill.

Now Curitiba collects and adequately disposes 100% of its municipal waste. Its score is also bolstered by progressive policies on waste collection and disposal, and waste recycling and re-use.

The city enforces strict environmental standards on its sole landfill and also has a programme to separately collect and treat hazardous waste, as well as debris from construction and demolition.

Curitiba also has the most advanced recycling programme in Brazil. On the other hand, the city generates 473 kg of waste per person per year, slightly more than the average (465 kg). Reducing the amount of waste generated would boost its already impressive performance in this category even more.

In 1989 Curitiba launched its now-renowned recycling programme. Residents separate recyclable materials, including glass, plastics, paper and old electronic devices, which the city collects from households three times a week. To ensure proper disposal of waste generated in 41 informal settlements, which have dense, winding streets that are difficult for waste companies to access, the city introduced its "Purchase of Garbage" initiative. The city has designated central collection points where residents receive food baskets in ex-change for each 8-10 kg of waste they hand over. Furthermore, the city pays the neighbourhood association 10% of the value of each food basket for community works or services. Curitiba authorities estimate that 6,800 tonnes of waste are collected through this initiative each year.

Water

Curitiba ranks above average in the water category. The city's water consumption is one of the lowest in Sud America. On a per capita basis, the city consumes 150 litres of water per day, well below the average of 264 litres. The low level of water consumption is largely attributable to many years of successful public awareness campaigns to encourage water conservation. Furthermore, Curitiba is the leading city for the strength of its water sustainability policy, which is contained in the city's municipal water resources plan.

The top marks for policy are driven by the presence of several efficiency measures, including water meters, separate pipes for non-drinking water, hose-pipe bans and rainwater collection. The city is marked down for only partially monitoring surface water quality and imposing limits for levels of pollutants in surface or drinking water. However, this result is skewed by the fact that the state-run environmental agency monitors water quality rather than the city itself. This should change though, as the city has plans to monitor water quality at 70 points throughout the city in the future.

The state water company has extended water services — as well as sewerage connections — to all of the 1,790 households in Vila Zumbi dos Palmares, an informal settlement. The programme guarantees the delivery of clean drinking water and also improves water quality for Curitiba as a whole, largely because the informal settlement sits along the banks of the Palmital River, one of the city's main water sources.

Sanitation

Curitiba ranks above average in sanitation. The city treats 98% of its wastewater, the third best performance in the Index, behind Brasília and Monterrey, and much higher than the 17-city average of 52%. Curitiba's score is also boosted by strict standards for wastewater treatment and regular monitoring, and the city promotes public awareness on the efficient use of sanitation systems. The city could work to improve sanitation access, however. Only

93% of residents have access to services, one of the lower rates in the Index and slightly below the average of 94%.

The main initiative to improve the Curitiba's sanitation system is a US$585 million state wide programme called "From River to River". This comprehensive plan involves improving sanitation, as well as drainage and the quality of the state's water basins. The programme will run since 2018.

Air quality

Curitiba ranks well above average in air quality. Along with Santiago, the city boasts the most advanced clean air policy in the Index. It regularly monitors air pollutants, for example, and participates in a statewide programme to inform citizens about the dangers of household pollutants. It also has a comprehensive air quality code, helping Curitiba achieve better than average pollutant levels.

The city records an average daily concentration of nitrogen dioxide at 23 micrograms per cubic metre, compared to the Index average of 38 micrograms. While still well below the average, the city's nitrogen dioxide emissions can likely be attributed to the city's continued reliance on motor vehicles — they are a primary source of this pollutant. The city also does well on sulphur dioxide and suspended particulate matter emissions, with both well below the average levels.

In 2002 the state government introduced a law that establishes strict emissions standards for industry, and mandates emissions audits at factories every four years. Authorities issue fines to facilities that do not meet standards, and if factories fail twice, the state can close them down.

Environmental governance

Curitiba ranks above average for environmental governance. It performs particularly well for environmental management, thanks to having a designated environmental department which monitors the city's environmental impact and drafts strategic plans on environmental policy. In 2010 the city allocated about US$106 million to the environmental department, or about 5% of the total city budget. Curitiba also actively engages citizens and NGOs in formulating environmental policy. As result, it gets the highest marks in the Index for public participation, along with Santiago. While Curitiba has conducted a recent baseline environmental review that included water, sanitation, waste, transport, human settlements and climate change, the review omitted air quality, land use and energy. Other Index cities included all of these components in their review.

In 1989 Curitiba added environmental education into the curriculum of its public schools. The school system adopted an interdisciplinary method for teaching conservation,

recycling and a wide range of environmental issues. The city provides training courses on environmental education for teachers and supports class fieldtrips to parks and forests" (*source: EIU*).

Quantitative indicators: Curitiba

		Average	Curitiba	Year*	Source
Energy and CO_2	CO_2 emissions from electricity consumption per person (kg/person)	202.2	70.4 [1, e]	2007	EIU estimate; Agência Curitiba; Curitiba, Prefeitura da Cidade; International Energy Agency; Intergovernmental Panel on Climate Change
	Electricity consumption per US$ GDP (megajoules per thousand US$ GDP)	760.7	743.5 [2]	2007	Agência Curitiba; Curitiba, Prefeitura da Cidade; Economist Intelligence Unit
Land use and Buildings	Population density (persons/km²)	4,503.0	4,296.2 [2]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
	Green spaces per person (m²/person)	254.6	51.5 [2]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
Transport	Length of mass transport network (km/km²)	5.0	8.5 [2, e]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
	Superior public transport networks (km/km²)	0.13	0.19 [2]	2010	URBS Curitiba
	Stock of cars and motorcycles (vehicles/person)	0.30	0.50 [2]	2010	Denatran
Waste	Share of waste collected and adequately disposed (%)	96.2	100.0 [2]	2007	Agência Curitiba; Curitiba, Prefeitura da Cidade
	Waste generated per person (kg/person/year)	465.0	473.2 [2]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
Water	Water consumption per person (litres per person per day)	264.3	150.0 [2]	2010	SANEPAR - Companhia de Saneamento do Paraná
	Water system leakages (%)	34.6	39.2 [2]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
	Share of population with access to potable water (%)	97.5	100.0 [2]	2009	Agência Curitiba; Curitiba, Prefeitura da Cidade
Sanitation	Population with access to sanitation (%)	93.7	92.5 [3]	2010	SANEPAR - Companhia de Saneamento do Paraná
	Share of wastewater treated (%)	51.5	98.3 [2]	2010	SANEPAR - Companhia de Saneamento do Paraná
Air Quality	Daily nitrogen dioxide levels (ug/m³)	37.8	22.5 [2]	2007	Secretaria de Estado do Meio Ambiente - Relatório de Qualidade do Ar Curitiba e RMC
	Daily sulphur dioxide levels (ug/m³)	11.4	6.6 [2]	2007	Secretaria de Estado do Meio Ambiente - Relatório de Qualidade do Ar Curitiba e RMC
	Daily suspended particulate matter levels (ug/m³)	48.0	25.9 [2]	2007	Secretaria de Estado do Meio Ambiente - Relatório de Qualidade do Ar Curitiba e RMC

Figure 18 - Curitiba Quantitative Indicators (*source: EIU*)

2.2 The case of São Paulo

Here below is presented an excerpt from the *Latin American Green City Index (pag. 96-99), 2012* by *The Economist Intelligent Unit*, that refers to the city of São Paulo.

"A teeming megacity with 20.7 million residents, São Paulo is Brazil's most populous metropolitan area. With 11 million people living inside the São Paulo city limits, the city is also the most populous in the Latin American Green City Index.

All data included in the Index is based on city figures, except for data on electricity consumption and CO2 emissions from electricity consumption, which are based on the metropolitan area.

São Paulo grew over the past century as a dynamic industrial hub, but its economy has been transformed in recent decades and is now dominated by services. Today it is Brazil's economic and financial capital, and a major centre for multinational companies operating in Latin America, though several big industries remain in the periphery of the city, including car manufacturers.

São Paulo generates around 12% of the country's GDP and has the fifth highest GDP per person in the Index, at US$ 15,100. Long a magnet for both Brazilians and foreign immigrants, São Paulo has over the past century experienced a massive population explosion

that has led to rapid and often chaotic urbanization. Despite the massive challenges posed by the size of its population, São Paulo ranks above average in the Latin American Green City index.

The city's strongest performance is in the energy and CO2 category, where it places well above average. This impressive placement is a result of very low CO2 emissions from electricity consumption and one of the most robust climate change action plans in the Index.

São Paulo places above average in all other categories with the exceptions of air quality and environmental governance. It ranks average in both categories due to the lack of a comprehensive clean air policy and a low level of public participation in environmental projects. São Paulo is, however, taking proactive steps to improve its environmental performance, receiving high scores for government policies in many categories.

Energy and CO2

São Paulo ranks well above average in energy and CO2. With all of its electricity generated by hydropower plants, São Paulo is unique in the Index for having an estimated zero CO2 emissions from electricity usage. This is considerably better than the 17-city average annual emissions rate of 202 kg per person per year. São Paulo also has some of the most comprehensive clean energy and climate change policies in the Index.

In 2005 the city conducted a full inventory of CO2 emissions which showed that transport was the largest single source of the city's emissions, followed by waste disposal. The São Paulo metropolitan region consumes 553 megajoules of electricity per US$ 1,000 of GDP, well below the Index average of 761 megajoules.

In 2009 São Paulo officials adopted an ambitious, comprehensive climate change policy, which commits the city to reduce CO2 and other greenhouse gas emissions by 30% of 2005 levels by 2012. The city also established a climate change committee to monitor progress. The city says it is has made impressive strides to meeting this goal. This rapid reduction is a result of two waste-to-energy conversion plants. The city closed operations at its two main landfills, Bandeirantes and São João, in 2007 and 2009, respectively, and installed thermoelectric power plants at both facilities. By capturing and burning methane, the landfills supply a total of 350,000 megawatt hours per year, and will cut CO2 emissions by 11 million tonnes through 2012.

Land use and buildings

São Paulo ranks above average in land use and buildings. The city proper has the fourth highest density in the Index, at 7,300 inhabitants per square kilometre, considerably higher than the 17-city average of 4,500 inhabitants per square kilometre. The city also has robust

eco-buildings policies, thanks to a local law requiring that all new buildings include solar panels for hot water, and new energy-efficiency standards that came into effect in 2009.

The city has 55 square metres of green spaces per person — a middling result among the 17 cities in the Index. With the exception of a few parks, São Paulo's dense inner city is relatively void of green spaces, but the city's result in this area would likely improve if the metropolitan area had been included. The city has significant room for improvement in the area of land use policy, with only partial efforts to contain urban sprawl and protect environmentally sensitive areas.

In 2009 São Paulo adopted Agenda 2012, which established a set of 223 short- and medium-term goals for the city. While the agenda covers a wide range of areas, from political transparency to social inclusion, among others, the initiative sets a series of goals in the area of land use and buildings. These include constructing 50 new neighbourhood parks and three parks along the Tietê River, in addition to planting 800,000 trees. Agenda 2012 also includes an initiative, run by the city's housing department, to install infrastructure and upgrade housing in 81 flood-prone informal settlements, expected to affect 75,000 families. The city is also in the process of upgrading housing, installing basic infrastructure and establishing waste recycling programmes in what were two of São Paulo's largest informal settlements, Heliopolis and Paraísopolis, as well as in other areas. As a result, these former settlements have evolved into low-income neighbourhoods.

Regarding buildings, a 2009 law requires all new municipal buildings to meet energy-efficiency standards and that existing buildings be retrofitted with technology to improve energy efficiency and to mitigate their environmental impact.

Transport

São Paulo ranks above average in the transport category, an impressive placement for a city widely known for its endemic traffic problems. And indeed, the city has one of the largest stocks of cars and motorcycles in the Index, 0.44 vehicles per person, compared to the 17-city average of 0.30. However, São Paulo is trying to limit the effects of the city's deeply entrenched car culture with comprehensive congestion-reduction policies. These include regulations limiting the number of cars entering the city centre and limited vehicle.

Despite progress the city still lacks other congestion reduction measures, such as carpooling lanes, congestion charges and park and ride systems, which would boost its score in this category. To further alleviate chronic congestion and encourage the use of public transport, the city and state are working together on a US$ 18 billion plan calling for new metro lines, new bus terminals, and improved traffic control and signalling by 2020.

São Paulo's metro is modern and relatively efficient but its coverage is limited to some 69 km and four main lines. The city is building a fifth line, but progress has been slow.

Nevertheless, the city's superior transport network (defined in the Index as transport that moves large numbers of passengers quickly in dedicated lanes, such as metro, bus rapid transit or tram networks) is the fifth longest superior transport network in the Index. It measures 0.21 km per square kilometre of city territory, which is twice the 17-city average of 0.10 km. Bus transport remains the most common form of public transport and the city boasts an extensive bus network, which, unlike the metro, covers all areas of São Paulo. Overall, the mass transport system within the city limits measures 7.5 km per square kilometre, well above the Index average of 5 km.

Officials prohibit 20% of the city's cars from entering a large portion of central São Paulo during peak hours of each work day. Restrictions are based on license plate numbers. For example, cars with license plates that end in specified digits are prohibited from entering the zone on certain days. Violators are subject to heavy fines and repeat offenders can lose their licenses. And in another move to reduce congestion, the city has since 2007 been widening a ban on heavy vehicles on certain high-volume avenues during peak hours.

Waste

São Paulo ranks above average in the waste category. According to official figures, São Paulo collects and adequately disposes of all of the waste produced in the city limits. Two private contractors collect residential and household waste, as well as recyclable materials. The waste is disposed of in two managed landfills. The city has a strong record in waste collection and disposal policies thanks to strict enforcement of environmental standards on its landfills and careful monitoring of the disposal of hazardous waste by industry. Despite its well-managed waste disposal programme, São Paulo produces 550 kg of waste per inhabitant per year, above the Index average of 465 kg.

São Paulo's "Ecopoint" initiative is reducing the illegal dumping of large waste items on city streets. The city has central collection points for residents to dispose, free of charge, items that do not fit in residential bins, up to one cubic metre in volume, such as furniture, tree cuttings and construction waste. The city has 48 collection centres. In the first six months of 2010 the city says it collected 57,400 cubic metres of waste that otherwise would have been left on the streets. By 2020 the city aims to have 96 stations in operation, which will offer access to a majority of the population.

Water

São Paulo ranks above average in the water category. The city performs particularly well in water quality policies thanks to close monitoring by the state-wide water company, Sabesp.

São Paulo consumes an average of 220 litres of water per person per day, according to official figures, slightly below the 17-city average of 264 litres. But the city appears committed to lowering consumption even further, having installed water meters in most residential buildings. Nearly all of the population living within the city limits has access to potable water, according to official sources. São Paulo loses 31% of its water to system leakages, which, though high, is below the 17-city average of 35%.

Sabesp, the state-wide water company, has prioritised the elimination of leaks and illegal connections to the water network. It has therefore increased the number of inspectors and adopted new technology that helps it monitor all of the water in the system, spotting major leaks quickly and forecasting water consumption levels based on outdoor temperatures.

Furthermore, Sabesp has an ongoing initiative called "PURA", to promote conservation in São Paulo through public information campaigns and water-saving technology. Using best practices developed in collaboration with the Polytechnic University of São Paulo, Sabesp works with institutions such as schools, hospitals and prisons to encourage conservation, repair leaks and install water conservation equipment. Sabesp says it has reduced water consumption in its own administrative offices by 72% and in municipal schools by 38%.

Sanitation

São Paulo ranks above average in the sanitation category. Ninety-nine percent of São Paulo's residents have access to sanitation, an estimate based on official figures, which is better than the 17-city average of 94%. The city does not do as well on the percentage of wastewater treated, but still better than the average, at 75% versus 52%. This means a large amount of untreated wastewater is still dumped into the city's main water source, the Tietê River. Sabesp, the state water company, closely monitors toxin levels in wastewater at treatment facilities, but São Paulo is one of the few cities in the Index that fails to monitor on-site treatment facilities, like septic tanks, in homes and communal areas.

The city is in the third and final phase of its long-term, US$ 1 billion sanitation expansion and improvement programme. By building 580 km of new effluent collectors and other infrastructure improvements, the city expects to be able to treat wastewater from an additional three million people in the metropolitan area when the project finishes in 2018. This would be a 41% improvement in capacity.

Air quality

São Paulo ranks average in the air quality category. Its average daily emissions of sulphur dioxide and suspended particulate matter are well below the 17-city averages.

Average daily nitrogen dioxide levels, however, are worse than average, at 47 micrograms per cubic metre compared to 38 micrograms, which can be attributed primarily to the prevalence of automobiles - the main source of air pollution in São Paulo.

The city has significant room to improve its clean air policies relative to other cities in the Index. In São Paulo, for example, air quality policies are coupled with wider initiatives to reduce traffic congestion, which is an important step given the impact cars have on the city's air quality. However, top-performers in this category have policies that specifically target all forms of air pollution.

Environmental governance

São Paulo ranks average in environmental governance. While the city has a designated environmental department, the level of policy implementation is limited and the level of public participation has remained relatively poor. Furthermore, responsibilities for transportation, water and sanitation are split between the city and state, causing some fragmentation in policy. However, the environmental department budget has tripled between 2004 and 2009, to about US$ 220 million, demonstrating the city's renewed interest in environmental projects" (*source: EIU*).

Quantitative indicators: Sao Paulo

		Average	Sao Paulo	Year*	Source
Energy and CO_2	CO_2 emissions from electricity consumption per person (kg/person)	202.2	0.0 [1, e]	2009	EIU estimate; AES
	Electricity consumption per US$ GDP (megajoules per thousand US$ GDP)	760.7	552.7 [2]	2007	AES; Instituto Brasileiro de Geografia e Estatística; Economist Intelligence Unit
Land use and Buildings	Population density (persons/km^2)	4,503.0	7,314.5 [3]	2009	Instituto Brasileiro de Geografia e Estatística
	Green spaces per person (m^2/person)	254.6	54.7 [3]	2009	Secretaría de Meio Ambiente; Instituto Brasileiro de Geografia e Estatística
Transport	Length of mass transport network (km/km^2)	5.0	7.5 [3]	2009	SPTrans
	Superior public transport networks (km/km^2)	0.13	0.21 [3]	2010	SPTrans, Secretaria dos Transportes Metropolitanos
	Stock of cars and motorcycles (vehicles/person)	0.30	0.44 [3]	2010	Denatran
Waste	Share of waste collected and adequately disposed (%)	96.2	100.0 [3]	2009	Prefeitura de Sao Paulo
	Waste generated per person (kg/person/year)	465.0	550.0 [3]	2009	Prefeitura de Sao Paulo – "Informacoes Gerais Portal da Prefeitura de Sao Paulo"
Water	Water consumption per person (litres per person per day)	264.3	220.5 [3]	2007	SABESP; Instituto Brasileiro de Geografia e Estatística
	Water system leakages (%)	34.6	30.8 [3]	2007	SABESP
	Share of population with access to potable water (%)	97.5	99.2 [3]	2007	SABESP; Instituto Brasileiro de Geografia e Estatística
Sanitation	Population with access to sanitation (%)	93.7	99.1 [4, e]	2009	SABESP; Instituto Brasileiro de Geografia e Estatística
	Share of wastewater treated (%)	51.5	75.0 [3]	2007	SABESP
Air Quality	Daily nitrogen dioxide levels (ug/m^3)	37.8	47.0 [3]	2009	Companhia Ambiental do Estado de São Paulo
	Daily sulphur dioxide levels (ug/m^3)	11.4	4.0 [3]	2009	Companhia Ambiental do Estado de São Paulo
	Daily suspended particulate matter levels (ug/m^3)	48.0	33.0 [3]	2009	Companhia Ambiental do Estado de São Paulo

Figure 19 - Sao Paulo Quantitative Indicators (*source: EIU*)

2.3 The case of Porto Alegre

Here below is presented an excerpt from the *Latin American Green City Index (pag. 76-79), 2012* by *The Economist Intelligent Unit*, that refers to the city of São Paulo.

"Porto Alegre is the capital of Brazil's southernmost state, Rio Grande do Sul. Long a magnet for foreign immigrants, the metropolitan area is now home to 4.7 million people. However, with a few exceptions noted below, data included in the Latin American Green City Index are based on figures for the city of Porto Alegre, which has 1.4 million residents.

Located at the confluence of five rivers, the city has a major port that serves as a transport hub for all of southern Brazil, and contributes significantly to the local economy. In particular, agricultural products from around the state pass through Porto Alegre before being exported around the world.

Services also play an important role in the city's economy, as do some heavy industries, including steel and car manufacturers. Porto Alegre ranks average overall in the Latin American Green City Index.

The city's best performance is in the waste category, where it ranks above average, thanks to a well-developed recycling programme and strong policies regarding waste collection and disposal. Porto Alegre achieves average rankings in the areas of land use and buildings, water, sanitation, and air quality. Despite its middling rank in water and sanitation, the city is one of a few in the Index that has achieved universal access to potable water and sanitation services, according to official figures. On the other hand, the city has significant room for improvement in energy and CO2, transport, and environmental governance. It places below average in these three categories.

Energy and CO2

Porto Alegre ranks below average in energy and CO2. Its poor performance in this category is attributable to the city's high electricity consumption, its failure to adopt a climate change action plan, and its mixed progress in clean energy policies. The metropolitan region consumes 974 megajoules of electricity per US$ 1,000 GDP, which is one of the highest rates in the Index and well above the 17-city average of 761 megajoules. Porto Alegre does not monitor greenhouse gas emissions and, while it is investing in developing clean and renewable sources of energy, the city earns only partial marks for its investment in waste-to energy programmes. On the other hand, with nearly 90% of its electricity already produced from renewable sources, primarily hydropower, the Porto Alegre metropolitan region has a much stronger record in terms of CO2 emissions from electricity. It emits an estimated 86 kg of CO2 per inhabitant annually in the metropolitan area, considerably lower than the Index average of 202 kg. Furthermore, Porto Alegre's performance in the energy and CO2 category will likely improve following the creation of a government body charged with guiding policy in the area of Renewable Energies.

In September 2009 the city's environmental department launched a new agency, the Resource Centre on Renewable Energies, to promote renewable energy in Porto Alegre. The

centre distributes information about renewable technologies, including details on installation costs and vendor names. The centre is also responsible for developing potential renewable energy policies.

Land use and buildings

Porto Alegre ranks average in the land use and buildings category. The population density, at 2,900 persons per square kilometre inside the city limits, falls below the 17-city average of 4,500 inhabitants. At the same time, the metropolitan region of Porto Alegre has one of the lowest amounts of green space in the Index, with only 6 square metres per person. Despite its small amount of green spaces, the city is making an effort to plant trees along city roads and in parks and to preserve native vegetation.

Porto Alegre also has strict guidelines for environmental licensing aimed at protecting conservation areas, boosting its performance in land use policies.

Likewise, the city performs well in the area of eco buildings policy. It has a well-developed set of standards to guarantee the eco-efficiency of new buildings and actively promotes awareness about ways for citizens to improve energy efficiency of buildings. On the other hand, it is one of several cities in the Index that does not incentivise businesses and households to lower their energy use.

While Porto Alegre lacks a comprehensive strategy aimed at improving energy efficiency in municipal buildings, the environmental secretariat has taken tentative steps in this direction, by using solar energy to heat water at one of its offices on an experimental basis.

The ten solar panels will capture enough energy to heat 600 litres of water a day. The city is also building 210 houses, as part of its social housing project, with solar-powered water heaters as an alternative to electric showers, which are common in much of Brazil.

Transport

Porto Alegre ranks below average for transport. The city has a higher-than-average stock of cars and motorcycles, at 0.38 vehicles per person, compared to the 17-city average of 0.30.

The length of the mass transport network is also shorter than average, at an estimated 3.6 km per square kilometre, compared to the Index average of 5 km.

The city performs well, however, for urban mass transport policies, thanks to its integrated pricing system and the presence of exclusive bus lanes. The city also has a traffic management system with 40 cameras connected to a central control room, where the traffic lights are managed according to the flow of vehicles.

Porto Alegre is investing US$380 million to extend the metro, adding 10 km and four stations towards the city's northern suburbs. Though long discussed, plans for a second metro line have not been specified. However, the city has unveiled a US$ 17 million project to construct a 1 km connection from the international airport to the metro, this so-called Aeromovel, an air-propelled train, is being financed by the federal government. Furthermore, the city is adding 40 km of bike lanes to encourage residents to use greener forms of transport.

Waste

Porto Alegre ranks above average in the waste category, its best performance in the Index. This is largely due to its waste collection and disposal policy, and a well-developed recycling and re-use programme. Recyclable material is collected twice a week, and local authorities run public information campaigns on recycling and waste reduction. Porto Alegre also does well on waste collection, gathering and disposing of 99% of the waste produced in the city limits. The city of Porto Alegre generates 345 kg of waste per person per year, compared to the Index average of 465 kg. In 1997 the city was one of the first in the country to open a managed landfill. It was closed in 2002 when it reached capacity, in favour of the privately run Recreio landfill, located 113 km outside of the city. And since 2006 the city has run a separate collection scheme for medical and other special forms of waste.

In August 2010, Porto Alegre announced a pilot project to place 1,000 household waste containers around the city, in an effort to reduce the amount of waste left on streets, improve transport logistics and cut back on collection time.

Water

Porto Alegre ranks average in the water category. The city's water company, DMAE, loses 29% of water to system leakages, which, though high, is still one of the lowest leakage rates in the Index, and below the average 35%. The city provides potable water to all of its residents, according to official figures.

The city lies on the eastern bank of the Guaiba Lake, at the convergence of five rivers, so as a result water is plentiful in Porto Alegre.

Porto Alegre also performs well in water sustainability policies thanks to public awareness campaigns promoting conservation. The city's water ranking is hindered, however, by relatively high-water consumption; the city consumes 313 litres per person per day, considerably more than the 17-city average of 264 litres.

In 2005 the city's water company launched the "Right Water" programme to reduce the number of clandestine links to the water network and expand access to potable water in informal settlements.

The city works with local residents' associations to identify and curb illegal connections, and offers grace periods and instalment plans for residents who cannot pay their water bills in full. The city says the delinquency rate has dropped from 14% a few years ago to less than 10% today.

Sanitation

Porto Alegre ranks average in the sanitation category. All of Porto Alegre's residents have access to sanitation services, according to official figures — well above the 17-city average of 94%. In contrast, the city treats only 20% of this wastewater, well below the Index average of 52%. However, Porto Alegre sees the need for improvement and has comprehensive sanitation policies in place, including an ambitious goal to significantly increase the share of wastewater treated.

In 2000 the city unveiled its comprehensive sanitation plan. The US$250 million "Pisa" project set a goal to increase wastewater treatment to 77%, although the city appears far from meeting that target. Fourteen projects are currently under way, including new wastewater treatment facilities, new pipes and effluent collectors and upgrades to existing pumping stations.

Air quality

Porto Alegre ranks average in air quality. Like many cities in the Index, road traffic is the primary source of air pollution. The city has one of the lowest concentrations of sulphur dioxide in the Index, with daily levels at an estimated 2 micrograms per cubic metre versus an Index average of 11 micrograms. Porto Alegre's daily concentration of particulate matter is 34 micrograms per cubic metre, less than the average of 48 micrograms. However, the city performs less well for nitrogen dioxide emissions, a primary cause of which is automobiles: average daily concentrations total an estimated 54 micrograms per cubic metre versus an Index average of 38 micrograms.

While the city operates two monitoring stations near major intersections that measure only particulate matter and carbon dioxide emissions, the state environmental protection agency operates three monitoring stations in Porto Alegre that check for a variety of air pollutants.

While many cities require cars to pass yearly emissions tests, the city of Porto Alegre instead performs random checks on trucks and buses, under its "Operation Clean Air" programme. City officials set up checkpoints along major streets and pull drivers aside for emissions tests. Vehicles that fail are impounded and owners can be fined.

Environmental governance

Porto Alegre ranks below average for environmental governance. The city hasn't conducted a baseline environmental review in the last five years, and environmental issues are split within various departments of the local government, which may hamper comprehensive action and lead to a lack of efficiency in policy implementation. However, Porto Alegre was the first major Brazilian city to establish an environmental secretariat in 1976, and the environmental department remains active in drafting legislation and guiding policy. The city also makes efforts to involve the public by guaranteeing access to environmental information.

In 1989 Porto Alegre became the first city in Brazil to adopt a "participatory budget" process, which has since become a model for cities around the country. Each year the city holds a series of neighborhoods, regional and citywide meetings where residents and elected delegates vote on a wide range of spending priorities, including for environmental areas such as transport and sanitation. Regarding sanitation, for example, city officials say the process has directly resulted in the expansion of services.

In 2009, Local Governments for Sustainability, an international association of which Porto Alegre is a member, named the city as one of five "model" cities to take part in a renewable energy initiative. With the organization's backing, model communities develop a sustainable energy strategy. The city created the Resource Centre on Renewable Energies as part of the programme, and is studying other potential projects" (*source: EIU*).

Quantitative indicators: Porto Alegre

		Average	Porto Alegre	Year*	Source
Energy and CO_2	CO_2 emissions from electricity consumption per person (kg/person)	202.2	85.6 [1, e]	2008 2008	EIU estimate; Balanco Energetico do RS/CEEE, Sulgas; International Energy Agency; Governo do Estado do Rio Grande do Sul; Intergovernmental Panel on Climate Change
	Electricity consumption per US$ GDP (megajoules per thousand US$ GDP)	760.7	973.7 [2, e]	2008	Balanco Energetico do RS/CEEE, Sulgas; Fundação de Economia e Estatística; Economist Intelligence Unit
Land use and Buildings	Population density (persons/km²)	4,503.0	2,895.0 [3]	2009	Fundação de Economia e Estatística; Instituto Brasileiro de Geografia e Estatística
	Green spaces per person (m²/person)	254.6	6.0 [4]	2008	Secretaría Municipal do Meio Ambiente; Fundação de Economia e Estatística
Transport	Length of mass transport network (km/km²)	5.0	3.6 [4, e]	2010	Porto Alegre Sanitation Secretariat; METROPLAN
	Superior public transport networks (km/km²)	0.13	0.02 [3]	2010	etpc Porto Alegre, Trensurb
	Stock of cars and motorcycles (vehicles/person)	0.30	0.38 [3]	2008	Denatran
Waste	Share of waste collected and adequately disposed (%)	96.2	98.6 [3, e]	2008	Departamento Municipal de Limpeza Urbana (DMLU)
	Waste generated per person (kg/person/year)	465.0	344.6 [3]	2008	Departamento Municipal de Limpeza Urbana (DMLU); Fundação de Economia e Estatística
Water	Water consumption per person (litres per person per day)	264.3	313.0 [3]	2008	Departamento Municipal de Água e Esgotos; Fundação de Economia e Estatística
	Water system leakages (%)	34.6	28.6 [3]	2009	Departamento Municipal de Água e Esgotos
	Share of population with access to potable water (%)	97.5	100.0 [3]		Departamento Municipal de Água e Esgotos
Sanitation	Population with access to sanitation (%)	93.7	100.0 [3, e]	2000	Instituto Brasileiro de Geografia e Estatística
	Share of wastewater treated (%)	51.5	20.0 [3]	2009	DMAE
Air Quality	Daily nitrogen dioxide levels (ug/m³)	37.8	53.8 [3, e]	2009	PROAR
	Daily sulphur dioxide levels (ug/m³)	11.4	1.9 [3, e]	2008	PROAR
	Daily suspended particulate matter levels (ug/m³)	48.0	34.3 [3]	2009	ECCPHA

Figure 20 - Porto Alegre Quantitative Indicators (*source: EIU*)

Chapter 3
Smart Cities Taxonomies

Once clarified what is meant by *smart city* and the needs that have induced cities to move towards a smarter configuration, it is necessary to identify a method capable of providing a measurement of the degree of smartness. The comparison between the most disparate urban areas through the results of the measurement allows the identification of the strengths and successful trends of the examined cities and the creation of a ranking of the most virtuous ones under the profile of smartness.

The first of the three parts of the current chapter shows some of these models, called taxonomies, which have been proposed over the time by various illustrious scholars, such as Giffinger (2007) and Cohen (2012). However, they have revealed some critical issues in practice, which have led to their overcoming.

In the second part, starting from the observation of the failure of these projects, inadequate to express the complexity that characterizes urban systems, we have analysed the taxonomy proposed in 2014 by Perboli et al. (2014).

Finally, the third part focuses on the analysis of various Brazilian projects in the field of smartness conducted through the application of this latest model. The choice to analyse the Smart City Projects (SCPs) of the aforementioned South American country is linked to our exchange experience at the University of São Paulo, which gave us the opportunity to see personally how cities are evolving and how governments and citizens promote projects for moving towards innovation and sustainability.

3.1 Giffinger's and Cohen's Taxonomies

The first chapter shows that urbanization is one of the main factors that has enhanced the birth of *Smart Cities*. In particular, from the UN dossier *World Urbanization Prospects 2018*

it emerged that currently 55% of the world population lives in urban areas and it is expected that this value will increase to 68% by 2050. Due to the urbanization and the consequent population increase, cities, which were not prepared for this huge growth, had to face various social, urban and natural problems that have undermined their economic and environmental balance.

The increase in CO2 emissions, the increase in traffic, pollution, inadequate energy consumption and the exasperated exploitation of natural resources are just some of the consequences of this expansion that have led governments to intervene and promote sustainable initiatives in order to restore balance in urban areas. In particular, it becomes necessary to rethink urban spaces in order to improve the quality of citizens' life and safeguard the environment through the rationalization of tangible and intangible assets.

Cities are moving towards a *Smart configuration*, thus becoming complex systems which, through the use of Digital Intelligence (DI), aim to meet the needs of their inhabitants, optimizing the use of resources and efficiency and reducing at the same time costs and waste.

Despite the recent proliferation of initiatives aimed at promoting the creation of smart cities, there still does not exist a univocal way to define the concept.

Initially it was believed that using Information and Communication Technologies (ICT) was enough to transform a city into a Smart City. However, although ICT facilitates the optimization of resources, coordinates and ensures interoperability between the various sensors, it is necessary but not sufficient technology to ensure the evolution of cities in a *smart* sense.

The absence of an agreed definition of *smart city* creates difficulties in identifying a methodology that measures the level of smartness of a city.

Taxonomy is the universal tool that allows to classify concepts hierarchically. In this specific case, the measurement model examines all projects related to smart cities and at the same time, it classifies cities based on their level of smartness. The complexity in defining a classification model suitable for any urban area is due to the fact that each city is characterized by different components and influenced by local factors.

3.1.1 Smart Cities Ranking of European medium-sized cities, 2007

The first attempts to measure the *smartness* of cities proved unsuitable, since they combined criteria that did not collimate with each other and ultimately provided inaccurate assessments. Furthermore, these models did not highlight the strengths and weaknesses of the cities analysed, so as not to favour neither a change nor the identification of a successful trend.

Smart cities Ranking of European medium-sized cities, 2007 was the first work that brought greater clarity in the classification of smart cities. Giffinger and the other scholars of the University of Vienna proposed a tool that did not give a univocal definition of what a smart city was. It instead analysed and evaluated the results that were achieved through six categories:

- ***Smart Economy***: the *smart economy* refers to the circumstance according to which the inhabitants generate new ideas and work in order to optimize revenues with the least possible effort. This concept is called the maximum productivity cycle. Cities will have to take advantage of the opportunities created by the introduction of technological innovations and the use of ICT in order to increase competitiveness in the market and to grow the local economy. In fact, the process of innovation of processes and services allows to optimize times and costs and, consequently, to increase profits.
- ***Smart Mobility***: the need for smart mobility is imposed by the rapid increase in population and urbanism that has upset the balance of cities. The main element on which smart mobility focuses is the increase in transport efficiency in urban and neighbouring areas, so as to be able to reduce energy consumption, pollution and traffic. An example is represented by GPS systems that provide the driver with real-time traffic information, thus also advising the optimal route to reach the destination. Another example of smart mobility is represented by the introduction of sharing mobility mechanisms (car sharing, bike sharing), that lead to a reduction in the number of vehicles on the road and the related CO2 emissions.
- ***Smart Environment***: Environmental protection is the main concern of the last decades. In order to satisfy their needs, citizens have caused serious environmental damages through activities that do not comply with sustainability. The smart environment involves the use of new technologies to offer more sustainable solutions, reducing the consumption of natural resources and reducing energy consumption, greenhouse gases and CO2 emissions. Functional for this purpose is the introduction of technological devices in the cities, such as sensors which allow to monitor air quality and pollution percentages in real time, so as to intervene to restore optimal conditions.
- ***Smart People***: in addition to innovation and new technologies, a crucial role in the evolution of a city towards a smarter configuration is played by citizens and human capital. In fact, it is absolutely essential the collaboration between administrations and inhabitants, who are asked to be smarter in terms of capabilities, attitudes and skills. It is imperative for this transformation the active

participation of citizens in the social sphere, which is favoured through initiatives, such as online consultation. In this way citizens, in addition to being users of goods and services offered by institutions, become protagonists of the transformation process of cities.

- ***Smart Living***: this axis focuses on improving the quality of life of the citizen.
  It starts from the assumption that cities and their inhabitants must be in a harmonious balance where technologies and innovations are used at the same time to meet the needs of citizens and improve the urban environment. In particular, the improvement of the quality of life of a citizen is ensured through intervention on various areas such as economic-social, safety and sustainability. As regards security, for example, data collection and the transmission of these in real time have allowed the creation of devices capable of circumscribing areas with high probability of aggression, so that the police can, in a preventive perspective, work to reduce the incidence of such events.
- ***Smart Governance***: Governments, as promoters and financiers of most *smart* initiatives, are an active part of the city change process. Smart Governance aims to operate in a transparent way and to involve citizens in the decision-making process, since with a greater participation of all the subjects of the city it is possible to start a process of improvement of urban areas.
  For example, digital platforms have been created to offer citizens a series of information and data on the city in relation to different areas (environment, politics, safety, etc.) and which, at the same time, can be enriched and interpreted by the citizens themselves, leading to the development of high value-added services.

Giffinger believed that a medium-sized city could be considered *intelligent* when, based on the combination of local data and the activities carried out by politicians, by the economy and the inhabitants themselves, it presents a lasting development over time, of the six characteristics mentioned above.

The model envisaged using the 6 categories as a basis for city analysis, to then integrate more specific factors. In order to obtain a reliable measurement and ranking, a transparent hierarchical structure was used, where each level depended on the results obtained from the lower one.

The pyramid structure included 4 levels, the top of which was occupied by the *target* or the smart city, followed by the six categories, factors and indicators respectively (Figure 21).

The result of the first work was the identification of 31 factors and 74 indicators (Figure 22 and 23).

The model proposed by Giffinger et alt revealed significant negative sides: indeed, it presented an undue mix of national and local indicators. In particular, while 65% of the indicators were based on local or regional data, 35% used national data and therefore could not be defined at an urban level. These critical issues have forced a rethinking of the model.

In the following years, in fact, scholars updated the proposed taxonomy, also trying to take into account the phenomenon of urbanization, arriving in 2015 with a model having 6 characteristics, 27 domains and 90 indicators.

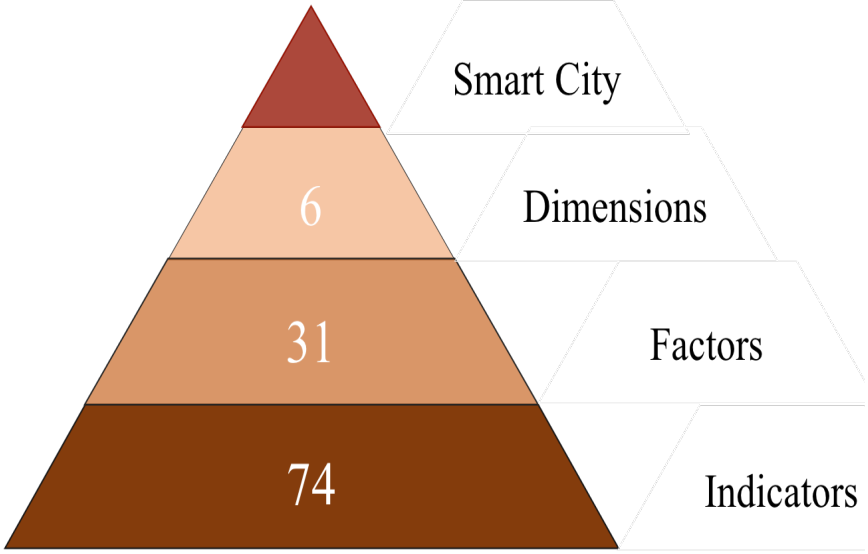


Figure 21 - Giffinger et alt. (2007) taxonomy structure

	factor	indicator	year	level
Smart Economy	Innovative spirit	R&D expenditure in % of GDP	2003	regional
		Employment rate in knowledge-intensive sectors	2004	regional
		Patent applications per inhabitant	2003	regional
	Entrepreneurship	Self-employment rate	2001	local
		New businesses registered	2001	local
	Economic image & trademarks	Importance as decision-making centre (HQ etc.)	2007	regional
	Productivity	GDP per employed person	2001	local
	Flexibility of labour market	Unemployment rate	2005	regional
		Proportion in part-time employment	2001	local
	International embeddedness	Companies with HQ in the city quoted on national stock market	2001	local
		Air transport of passengers	2003	regional
		Air transport of freight	2003	regional
Smart People	Level of qualification	Importance as knowledge centre (top research centres, top universities etc.)	2007	regional
		Population qualified at levels 5-6 ISCED	2001	local
		Foreign language skills	2005	national
	Affinity to life long learning	Book loans per resident	2001	local
		Participation in life-long-learning in %	2005	regional
		Participation in language courses	2005	national
	Social and ethnic plurality	Share of foreigners	2001	local
		Share of nationals born abroad	2001	local
	Flexibility	Perception of getting a new job	2006	national
	Creativity	Share of people working in creative industries	2002	national
	Cosmopolitanism/ Open-mindedness	Voters turnout at European elections	2001	local
		Immigration-friendly environment (attitude towards immigration)	2006	national
		Knowledge about the EU	2006	national
	Participation in public life	Voters turnout at city elections	2001	local
		Participation in voluntary work	2004	national
Smart Governance	Participation in decision-making	City representatives per resident	2001	local
		Political activity of inhabitants	2004	national
		Importance of politics for inhabitants	2006	national
		Share of female city representatives	2001	local
	Public and social services	Expenditure of the municipal per resident in PPS	2001	local
		Share of children in day care	2001	local
		Satisfaction with quality of schools	2005	national
	Transparent governance	Satisfaction with transparency of bureaucracy	2005	national
		Satisfaction with fight against corruption	2005	national

Figure 22 - Giffinger et alt. taxonomy categories (1)

	factor	indicator	year	level
Smart Mobility	Local accessibility	Public transport network per inhabitant	2001	local
		Satisfaction with access to public transport	2004	national
		Satisfaction with quality of public transport	2004	national
	(Inter-)national accessibility	International accessibility	2001	regional
	Availability of ICT-infrastructure	Computers in households	2006	national
		Broadband internet access in households	2006	national
	Sustainable, innovative and safe transport systems	Green mobility share (non-motorized individual traffic)	2001	local
		Traffic safety	2001	local
		Use of economical cars	2006	national
Smart Environment	Attractivity of natural conditions	Sunshine hours	2001	local
		Green space share	2001	local
	Pollution	Summer smog (Ozon)	2001	local
		Particulate matter	2001	local
		Fatal chronic lower respiratory diseases per inhabitant	2004	regional
	Environmental protection	Individual efforts on protecting nature	2004	national
		Opinion on nature protection	2006	national
	Sustainable resource management	Efficient use of water (use per GDP)	2001	local
		Efficient use of electricity (use per GDP)	2001	local
Smart Living	Cultural facilities	Cinema attendance per inhabitant	2001	local
		Museums visits per inhabitant	2001	local
		Theatre attendance per inhabitant	2001	local
	Health conditions	Life expectancy	2001	local
		Hospital beds per inhabitant	2001	local
		Doctors per inhabitant	2001	local
		Satisfaction with quality of health system	2004	national
	Individual safety	Crime rate	2001	local
		Death rate by assault	2001-03	regional
		Satisfaction with personal safety	2004	national
	Housing quality	Share of housing fulfilling minimal standards	2001	local
		Average living area per inhabitant	2001	local
		Satisfaction with personal housing situation	2004	national
	Education facilities	Students per inhabitant	2001	local
		Satisfaction with access to educational system	2004	national
		Satisfaction with quality of educational system	2004	national
	Touristic attractivity	Importance as tourist location (overnights, sights)	2007	regional
		Overnights per year per resident	2001	local
	Social cohesion	Perception on personal risk of poverty	2006	national
		Poverty rate	2005	national

Figure 23 - Giffinger et alt. taxonomy categories (2)

3.1.2 Smart City Wheel, 2012

Giffinger's taxonomy was followed by the elaboration of the model of Boyd Cohen, an urban and climate strategist who works in the area of sustainable development and smart cities.

The scientist defined smart cities as *"A broad, integrated approach to improving the efficiency of city operations, the quality of life for its citizens, and growing the local economy"*, (*Fast company, 09/09/2012*). Starting from this definition and from the study of the various projects, the author sought to create a universal taxonomy to measure the level of smartness of each city worldwide.

That model, called *Smart City Wheel*, used the six classification categories previously identified by the *Smart cities Ranking of European medium-sized cities, 2007* model by Giffinger et alt. and to each of these, three factors were associated (Figure 24).

The complexity encountered by this approach lay in identifying the indicators that were able to measure the various factors and that at the same time made it possible to compare similar cities by means of the wheel.

Through a progressive skimming operation, the author, starting from the selection of 400 indicators, managed to identify 62 of them. In particular, the model presented in 2014 consisted of 6 categories, 18 factors and 62 indicators, 16 of which were present in the new sustainable cities ISO standard, *ISO 37120* (Figure 25). As for the functioning of the same, it was expected that to evaluate the smartness of a city, a score would be assigned to each category. The city with very high performances was awarded a maximum score of 15 points.

Moreover, although this model was used to classify some cities, it was considered by many to be difficult to use. *"Given the difficulties cities had in responding to this survey, we will need to rethink the methodology going forward. The hope is to have as many cities (large and small) from around the globe participating in a way that permits them to benchmark themselves against other similar cities, and of course, to facilitate knowledge sharing among the private sector and citizen groups"*, (*Fast company, 20/11/2014*).

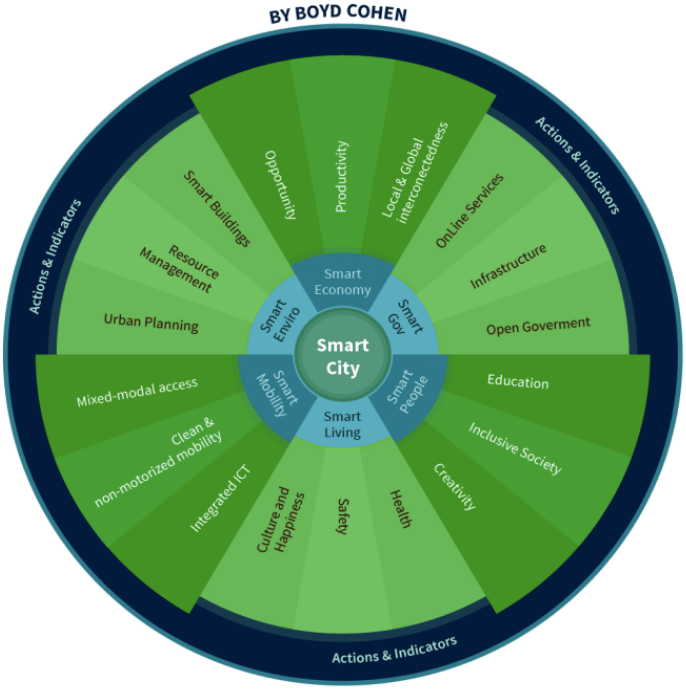


Figure 24 - Smart City Wheel (1)

Dimension	Working area	Indicators
Environment	Smart Buildings	Sustainability Certified Buildings Smart homes
	Resources Management	Energy Carbon Footprint Air quality Water consumption
	Sustainable Urban Planning	Climate resilience Planning Density Green Space per capita
Mobility	Efficient Transport	Clean-Energy Transport
	Multi-modal Access	Public Transport
	Technology Infrastructures	Smart Cards Access to real-time Information
Government	Online Services	Online Procedures Electronic Benefits Payments
	Infrastructure	Wi-Fi Coverage Broadband Coverage Sensor Coverage Integrated Health + Safety Operations
	Open Government	Open Data Open Apps Privacy
Economy	Entrepreneurship and Innovation	New start-ups R&D Employment levels Innovations
	Productivity	GRP per Capita
	Local and Global Connection	Exports International Events Hold
People	Inclusion	Internet-connected Households Smartphone penetration Civic engagement
	Education	Secondary Education University graduates
	Creativity	Foreign-born immigrants Urban living LAB Creative Industry jobs
Living	Cultural Well-Being	Life Condition Gini Index Quality of life ranking
	Safety	Crime

Figure 25 - Smart City Wheel (2)

3.2 Perboli et al. Taxonomy, 2014

As we have seen in previous paragraphs, it is still difficult to identify a unique methodology for classifying Smart Cities. For this reason, there is still a bit of scepticism towards projects on Smart Cities, people do not know how these could change their lives and many times they could be frightened by such changes, thus curbing their spread.

Furthermore, since there is no single definition, there is not even a database both nationally and internationally that contains projects already in force. This aspect leads the SCPs' proposers to devise similar projects and therefore to a lower effectiveness of the same.

In the past, many researchers have proposed very confusing classifications and taxonomies on Smart Cities, but no one had yet provided a 360° analysis of this concept. For example, Giffinger's and Cohen's taxonomies, previously analysed, were the first works able to provide greater clarity on how the intelligence of a city could be measured. The strength of these models was the identification of six categories, which were the starting point for subsequent studies.

However, these approaches were too general to be able to describe cities in their complexity, to the extent that they did not take due account of the phenomena that characterize the current urban scenario, such as, for example, urbanization.

These critical issues therefore led to the overcoming of the aforementioned models and the emergence of the need to find a complete taxonomy.

An answer to this requirement was provided by the Smart City Projects (SCPs) measurement model proposed by Professor Perboli et al. (2014), which aims to provide clear guidelines to define and frame every single aspect of Smart City Projects (SCPs).

Perboli et al. (2014) proposed a categorization of the SCPs that takes into account every single element and this allows to derive a trend from the projects already implemented, in order to highlight the main needs in a given city or country.

The taxonomy they propose provides for an analysis guided by 3 axes that represent the 3 dimensions that characterize an SCPs. These axes consist of:

- ***Description***;
- ***Business Model***;
- ***Purpose***.

As shown in Figure 26, each dimension is structured in subcategories and each category is composed of various elements.

Description			
Objectives	Tools	Project initiator	Stakeholders
Water	*Cloud Computing*	*Private*	*City*
E-Governance	*Data Base*	*Public*	*Consumers / Citizens*
Buildings	*DSS*	*Mixed*	*Administration*
CO_2 Emissions	*ICT*		*SMEs*
Energy	*Innovative Sensors*		*University*
Security	*Legal and financial tools*		
Social Innovation	*Other new technologies*		
Transportation	*Portable Smart Devices*		
	Smart Grids		

Business Model			Purpose		
Management	Infrastructure financing	Financial Resources	Client	Product	Geographical target
Private	*Private*	*Private*	*Private*	*Specific*	*Urban*
Public	*Public*	*Public*	*Public*	*No Specific*	*National*
Mixed			*Mixed*		*International*

Figure 26 - Perboli et alt. (2014) taxonomy

This taxonomy aims to be able to carry out a comparative analysis of different projects in order to highlight the elements of weakness and success of each. In this way, it is possible to define a general trend of the projects, identifying the elements on which financiers and other active parts of the city can invest for improving the performance of a city, directing it towards a smarter perspective.

In the following paragraphs we will go into detail about each axis, providing an analysis and a complete description of each of its components, and subsequently we will see how this taxonomy is applied to real SCPs present in Brazil. As already mentioned, the choice of Brazil is due to our recent experience in the South American state with the consequent possibility of seeing and testing on our skin the advantages that these projects have brought and will bring to the population.

3.2.1 Description

The axis *Description* allows the reader to immediately identify the content and context in which the SPCs develop. It contains the elements from which the idea of the project was born, from which the creator of this SCPs starts to implement it. The categories that make up this dimension are therefore:

- ***Objectives***;
- ***Tools***;
- ***Project initiator***;

- ***Stakeholders***.

Each of this category is made up of various criteria that more clearly outline the perimeter within which an SPCs extends.

Objectives

Each SCPs is intended to improve the quality of life of the people who live in that city or nation. To achieve this, there are many goals that can be pursued. The taxonomy introduced by Perboli et al. (2014) has identified 8 main objectives which, through the use of adequate technologies, can lead to net improvements in citizens' lives.

Many times, a single project can bring benefits in different areas; in this case we are therefore talking about *multi-objective* projects.

- ***Water***. Water is a fundamental element in our existence: we are made up of 75% of water, what we eat is made up of water. However, due to climate change, the quantity and quality of water are at risk. Solutions are therefore needed that aim to minimize waste and ensure the quality of the water we use. It is therefore important:
  - Detect leaks: due to population growth and water scarcity, the management of water leaks is becoming increasingly important. Recent studies have shown that to date the amount of water that is lost without use is equal to 25% of the total. These losses can be reduced by using sensors in the distribution network to provide real-time information on pressure, flows and quality;
  - Detect pollution: in addition to detecting water leaks, sensors can help monitor the quality of surface water in real time. Traditionally, this monitoring was performed manually with sample operations, causing a delay between the emergence and the detection of pollution;
  - Predicting floods: through predictive analyses by crossing meteorological data with geographic data, cities at risk can predict flood areas and probable times. The information obtained can be used to redirect traffic and warn inhabitants of areas at risk in advance;
  - Plan predictive maintenance: water infrastructures are complex buildings that require careful maintenance. To plan these interventions, it is advantageous to cross the use of sensors, which provide information on flow, pressure, acoustic signals, etc., with other data sources, such as insurance claims caused by floods, data from geographic information systems, etc. in this way it is possible to direct maintenance interventions on the parts of the water infrastructure that need it most.

- ***E-Governance***. A good relationship between government structures and citizens is essential for the correct performance of a company. When problems arise between these two entities, the company goes through a period of crisis and insecurity. The use of ICT improves the effectiveness, efficiency, transparency and communication that regulate relations between government and public administration, and citizens. The implementation of new technologies facilitates the identification of problems, the search for the origins of these problems and the development of solutions that aim to solve them and, therefore, to increase the quality of life of the inhabitants.
- ***Buildings***. In the construction sector, the goal for the future is to improve building automation, life safety and telecommunications. The installation of innovative sensors, the integration of ICT, etc. allow to reduce energy consumption, optimize the use of spaces and minimize the environmental impact. In particular, it becomes possible:
    - Combine energy consumption with the related activity: use innovative sensors to obtain detailed and real-time information on both consumption and building conditions;
    - Make energy consumption dynamic: buildings are able to adapt their energy consumption based on the request of the entire system in real time;
    - Take advantage of smart fills: reduce costs and waste by implementing automatic refills on machinery in buildings when their level (of water, oil, etc.) is running low;
    - Plan targeted cleaning: using fine-grained sensor networks, it becomes possible to identify the areas of a building that are most frequented in order to concentrate cleaning operations in these areas;
    - Automate parking in the garage: by detecting the license plate of the car, if the person who owns the license plate has permission, the garage door opens automatically and the parking space reserved for that guest is indicated;
    - Use renewable energy sources: a building can create, through solar panels or storage of thermal energy, more energy than it consumes.
- ***CO2 emissions***. Urban areas are responsible for 80% of CO2 emissions worldwide. Industrial centres and transport systems generate significant quantities of CO2, which is one of the causes of the ozone hole that has been leading to worrying climate change in recent years. Traffic congestion, factories, time spent looking for parking and many others all contribute to the generation

of carbon dioxide that is upsetting the world in which we live and therefore action is needed to cut CO2 emissions and other greenhouse gases. Better urban planning and changes in people's behaviour, integrated with new technologies, can be a first step towards reducing CO2 emissions.

- ***Energy***. Certainly, one of the most important and advantageous aspects of Smart Cities concerns the energy system. The least waste of energy, as well as the introduction of new energy sources and the consequent reduction in the use of energy produced from fossil fuels are among the main objectives in this area and it is possible to achieve them through:
    - Capillary distribution of renewable sources: unlike today, this will lead to the generation of energy through renewable sources (solar, water, thermal, etc.) in a greater number of plants with less capacity;
    - Smart Grids: the evolution of the classic transmission and distribution networks into intelligent networks that will be able to produce and consume energy, as well as allowing the transfer of data that allow the user to manage energy;
    - Microgrid: local grids disconnected from the national grid that allow to reduce energy losses, increasing the efficiency of the energy supply;
    - Intelligent measurement: an intelligent meter that allows energy supply companies to introduce price differentiation based on the season and time;
    - Reduction of consumption through gamification: providing users with tools that use concepts such as gamification to make them more aware of their consumption and influence them to modify their behaviour to reduce energy consumption;
    - Reactive devices: make household appliances reactive so that they temporarily stop consuming energy at times when demand increases and thus reducing the need for expensive spare capacity needed only in the event of peak use;
    - Seasonal storage of thermal energy (STES): store the heat that buildings produce during the summer season and then use it during the winter season;
    - Excessive use of heat: use the heat produced by the functions performed inside a building for other purposes (for example, use the heat generated by data centres to heat the water used for heating buildings);
    - Charging of electric vehicles: storing energy in electric vehicles during production peaks and supplying additional energy during consumption peaks;

- Combined power: there is a greater impact when the technological developments mentioned above work together;
- Cooperation in energy markets: cooperation between companies and governments and between companies themselves is needed to obtain the greatest benefits from the combination of these technological developments.

- ***Security***. Physical security is another aspect to which an SCP can bring benefits. The integration of ICT and other technologies provide solutions in this area such as intelligent street lighting, drones for risk assessment, data-based crime prevention programs, preventive crime analysis, emergency apps, acoustic sensors to detect the shots, etc. The implementation of these solutions ensures greater protection of citizens from violent crimes and provides more timely aid in case of emergencies.
- ***Social Innovation***. The Smart City concept was born with the idea of satisfying a need and consequently improving the quality of life of citizens. This is made possible by the implementation of solutions and services that exploit ICT and other new technologies that offer significant benefits to those who use them. Above we have already listed the main sectors in which SCPs develop, but these projects also offer advantages in terms of digitization of education, personalization of medical treatments through big data, 3D printing, blockchain, self-awareness of the state of health through wearable devices, peer-to-peer lendings, crowd management through advanced analytics, etc. From education to tourism, passing through the retail sector, SCPs provide solutions to daily problems by increasing the quality and perception of citizens' lives.
- ***Transportation***. Bringing improvements to the transport sector, in addition to reducing CO2 emissions as already explained above, also means reducing noise and congestion and simplifying the way in which inhabitants use any type of transport system. Solutions in this area vary from solutions that optimize the current transportation system to solutions that create completely new transportation systems. Some interventions in this sector are:
  - Smart parking 1: use sensors to locate available free parking in the city;
  - Smart parking 2: allow to book company car parks online in the evening and on weekends;
  - Peer-to-peer ride services: allow people to sell rides to other people who need transportation;
  - Personalized transport information: use technology and data to provide real-time and completely personalized transport indications;

- Intelligent traffic control: exploit sensors in infrastructures and vehicles to allow intelligent systems to optimize the flow of traffic by regulating traffic lights and other signals;
- Adaptive connected cars: to equip modern cars with computerized systems to increase convenience and safety;
- Shared self-driving cars: use self-driving vehicles to establish a strong reduction in the total number of cars and parking in the city.

Tools

The main component of a Smart City is technology. All the innovations proposed above would not exist without the technological revolution that our world has been undergoing in the last decade. These new tools provide a valuable contribution at every stage of the project, from the analysis of the problem through the help, for example, of Big Data to the implementation with the integration of ICT and innovative sensors. These are just some examples of possible applications and, as we have already seen, the types of technologies to be used are numerous, but Perboli et al. (2014) did they spot nine main categories, which are those most used in SCPs.

- ***Cloud Computing***. Literally *computer cloud*, a term that refers to the technology that allows you to process and store data on the network. In other words, through the Internet, Cloud Computing allows access to applications and data stored on remote hardware instead of on the local workstation. For large companies it therefore implies a significant reduction in costs; powerful hardware (expensive and subject to frequent maintenance) is no longer needed, but a machine capable of operating the *cloud access application* is sufficient. However, there is no lack of perplexity; on the one hand the files are only accessible via the network, on the other (despite the reassurances of the suppliers) there is concern for the security of sensitive data. Cloud Computing can make hardware available remotely (IaaS - Infrastructure as a Service), software platforms (PaaS - Platform as a Service) or software remotely (SaaS - Software as a Service).
- ***Data Base***. Organized set of data managed by a Data Base Management System (DBMS). Its characteristics are size, shareability and persistence: a database is large because in general has a size that requires the use of secondary memory for its management, shared, because it is accessible by multiple applications and users, and persistent, because it has a life cycle independent from that of the programs that use it. For the management of databases, specific languages have been designed that can be divided into two categories, not necessarily distinct:

data definition languages (DDL) and data manipulation languages (DML); the most famous is the SQL language.

- ***Decision Support Systems (DSS)***. Computerized decision support system. Since a decision is a choice between alternatives based on the outcome of an evaluation of the reasons for and against each option, the decision support concerns the process of estimating, evaluating and comparing solutions. This presupposes an organization and management subsystem of available data and information (database, knowledge base), a management subsystem and solution of available models (decision-making, forecasting, evaluation, etc.), a user interface for an efficient use of the models, the database and the information available. For decisions relating to a specialist sector, expert systems are used that exploit the computer's ability to store and process information to create a specialist knowledge base and to logically process such knowledge by imitating the deductive process of a human expert.
- ***Information and Communications Technologies (ICT)***. Technologies relating to integrated telecommunication systems (wired and wireless communication lines), computers, audio-video technologies and related software, which allow users to create, store and exchange information. Significant economic incentives favour this integration process, promoting the growth of companies active in the sector. ICTs present the characteristics of 'general purpose technology': they are an input with a decreasing cost over time, with vast applications, potentially pervasive, capable of reducing both the burden of the other inputs and the price of the 'output, at the same time affecting the quality of the products.
- ***Innovative Sensors***. Type of sensor that has electronic circuits inside which, in addition to detecting a physical, chemical or electrical quantity, can also process information and transmit it externally in the form of a digital signal. The microprocessor generally contains both the database and the program for processing the information. The connection of intelligent sensors with systems designed to collect their data is a concrete element of innovation, especially in relation to the widespread need to be able to connect a transducer to the control system with maximum simplicity and reliability.
- ***Legal and financial tools***. Tools that optimize classic services related to the financial sector such as the digitalization of courts and legal procedures, as well as the tools that led to the growth and spread of FinTech.
- ***Other new technologies***. Other tools that exploit innovative technologies capable of externally transmitting information that can increase the efficiency of

the expected service. An example are the products that use RFID technology which, in addition to providing the same service as traditional bar codes, are able to transmit data relating to the associated product to optimize logistical, commercial and identification processes in general.

- ***Portable Smart Devices***. An electronic device, generally connected to other devices or networks via different wireless protocols such as Bluetooth, Zigbee, NFC, Wi-Fi, LiFi, 3G, etc., that can operate to some extent interactively and autonomously. Several notable types of smart devices are smartphones, smart cars, smart thermostats, tablets, smartwatches and others. The term can also refer to a device that exhibits some properties of ubiquitous computing, including, although not necessarily, artificial intelligence.
- ***Smart Grids***. The set of an information network and an electrical distribution network in such a way as to allow the management of the electrical network in an *intelligent* way in various aspects or functions or in an efficient manner for the distribution of electricity and for more rational energy while minimizing any overloads and changes in the electrical voltage around its nominal value.

Project initiator

SCPs are projects from which everyone can benefit. For this reason, both governments and public administrations, and private companies have an interest in the implementation and development of these projects. We can summarize the reasons that push the two bodies to make proposals for smart cities in the following way: on the one hand public institutions offer incentives to SCPs initiatives to improve the sustainability and security of the city, on the other hand private institutions intend to earn greater efficiency and obtaining competitive advantages. In general, it is very common to find SCPs initiatives promoted by a combination of private and public bodies, for this reason there are three categories identified in the taxonomy as a project initiator.

- ***Private***. One or more private sector institutions that promote SCPs initiatives through federal laws, new favourable taxes on taxes and more to achieve a better quality of life for the inhabitants and to solve problems that otherwise should be managed by public bodies (for example crime).
- ***Public***. One or more public sector institutions wishing to gain a competitive advantage and greater efficiency. Small-medium enterprises (SMEs) seek to obtain a greater reputation by promoting SCPs initiatives, in order to attract new customers and gain an advantage over competitors.

- ***Mixed***. A combination of the categories described above. A collaboration between private and public bodies aims to promote new SCPs or to consolidate existing projects.

Stakeholders

Each project has people and / or structures involved in its development, both minimally and very directly. These people are the stakeholders, i.e. all the subjects, individuals or organizations actively involved in an economic initiative (project, company), whose interest is negatively or positively influenced by the result of the execution, or by the progress, of the initiative and whose action or reaction in turn influences the stages or completion of a project or the fate of an organization. In particular, the taxonomy of Perboli et al. (2014) identified five categories of stakeholders.

- ***City***. Obviously, cities are influenced by the implementation of SCPs. These projects incredibly modify the structure of the cities in which they are developed, creating new ways to manage traffic, to optimize the use of water, to reduce energy waste and much more.
- ***Consumers / Citizens***. As is easily understood, all the advantages that the creation of a SCP (such as those mentioned above) positively influence the lives of consumers, or citizens. They are the ones who derive the most evident advantages because these projects have the primary purpose of improving the quality of life of the inhabitants. Furthermore, citizens are directly involved in the analysis phase, as SCPs start from the needs of people.
- ***Administration***. Administrations and governments play a fundamental role in SCPs. They can take on the role of promoters and financiers of these initiatives since improving the quality of life of their citizens is their primary interest. Furthermore, by showing themselves as a *state of the art* and self-sustainable government, they would also gain advantages in terms of superiority compared to other countries.
- ***SMEs***. Small and medium sized companies and private companies are another very important player in the growth of a SCP. In fact, they are the ones who provide the innovative tools that guide these projects in exchange for economic and reputation benefits. In fact, as it applies to Administration, SMEs can gain the reputation of cutting-edge companies that believe in a better world.
- ***Universities***. Finally, universities, through its students and researchers, are able to provide the technological innovation that allows the creation of SCPs. Research and scientific publications produced by the university guide the promoters of Smart Cities in conceiving the model of city that would respond to the needs that

emerged. Furthermore, the university context is a good test environment for SCPs because it has the resources to simulate some aspects of the project without influencing other structures.

3.2.2 Business Model

Business models are strongly connected to technological innovations. The analysis of different areas highlights that innovation leads to revolution, revolution leads to change, and the most drastic and extreme change is what happens in people's minds. The spread of streaming services, that have overhung the traditional ones, is a clear example of digital evolution. It is in a context of technological revolution that a new business model must be specified and identified. A business model is simply the way a company creates, distributes and captures value. In our specific case, we focus on how a city creates, distributes and captures value.

The more an organization generates value for its customers (citizens, universities and others), the greater the success. Since the purpose of Smart Cities is to meet the needs of their inhabitants by create value for them, this paragraph aims to determine the ways in which SCPs manage to do it. For this reason, the taxonomy defined by Perboli et al. (2014) has identified three categories for this axis: Management, Infrastructure financing and Financial Resources. The three groups respectively represent who manages the project, who supplies the infrastructures and who economically supports the activities.

Management

As we have already anticipated, in these paragraphs we will define how the previously defined objectives can be achieved. A Smart City is an organization and therefore, it is necessary to identify the structure that will manage it. This structure is called *Management*, which is defined as the set of actions to be implemented so that an organization can pursue the objectives set in business planning and make choices regarding the relationships between its constituent elements (people and technologies) (Wikipedia). Depending on the type of project, in particular, depending on the set objectives and the impacts that these will have on the environment, the managers and the management methods of the SCPs will be different. Perboli et al. (2014) managed to classify these elements into three categories.

- ***Private***. A company or a partnership of multiple companies that aim to increase their business by providing services and products that will improve the lives of the people who use them.
- ***Public***. A public body or a partnership of several institutions, as the primary purpose of a Smart City is to improve citizens' quality of life.

- ***Mixed***. The combination of public and private institutions, which jointly commit to achieve a common purpose.

Infrastructure financing

After identifying which entity makes the choices, allocates the risk and manages the project in general, it is essential to understand who provides the means to do this. In this paragraph we will deal with the infrastructures, therefore we will see who the actors are that supply them. infrastructures mean all set of public works, to which we also give the name of social fixed capital, which form the basis of a country's economic and social development and, by analogy, also those activities that translate into capital formation personnel. Depending on the purpose of the SCP, the origin of the infrastructures will be different and, in this case, the taxonomy identifies two categories of institutions that provide infrastructures.

- ***Private***. Private organizations that provide the necessary infrastructure to achieve the objectives set by the project.
- ***Public***. Public institutions for everything that will improve citizens' quality of life.

Although not present in the taxonomy, collaboration between public and private entities is possible.

Financial resources

In addition to infrastructure, the other essential element for the success of a project is financial resources, or the sources of funding available to organizations for the acquisition of production factors. As with infrastructure, taxonomy has divided these organizations into two categories.

- ***Private***. Private companies that support the project with financial resources.
- ***Public***. Public bodies that invest in the project.

3.2.3 Purpose

The last axis of the taxonomy defines the final results of the project, understood as the type of the customer that the project will reach, the type of product that the project will offer and the territorial diffusion of the project. So, as it is easy to understand, we will have three categories to represent this dimension.

Client

SCPs can reach infinite categories of end users: citizens, SMEs, universities, voluntary associations and many others. We can therefore say that Smart Cities are intended for three types of customers.

- ***Private***. All users of private nature belong to this category.
- ***Public***. This category includes all public organizations, but also governments and administrations themselves.
- ***Mixed***. When a SCP reaches both private and public clients.

Product

In general, projects have a clear idea of what they want to create, or what the final product of the work will be. Sometimes, however, there is the case in which a project has not yet defined what the final result will be, since the research and development phases are not completed. In this sense, therefore, there are two types of products.

- ***Specific***. A result that has already been defined in the early stages of the project.
- ***No Specific***. When the product has yet to be defined.

Geographical target

From the name *Smart City*, it could be deduced that SCPs have an urban diffusion. In reality, this type of project can have more extensive impacts. In fact, SCPs also exist at national and international level and, for this reason, taxonomy defines three categories.

- ***Urban***. When the project impacts a single city.
- ***National***. When the project involves two or more cities in the same country.
- ***International***. When the project affects more than one country.

3.3 Brazilian Scenario

Brazil is the fifth largest state in the world by total area (8.5 million km2) and hosts 210,147,125 inhabitants, 82% of whom live in urban areas.

The country is part of a geo-economic aggregate, identified by the acronym BRICS (Brazil, Russia, India, China and South Africa), which includes countries that share some characteristics, including:

- the condition of developing economies;
- a large population;
- a vast territory;

- abundant strategic natural resources;
- strong GDP and share growth in world trade.

In fact, despite the economic crisis, Brazil is considered a country with high growth potential, for the natural resources present in the area, which incentivize the other power countries to invest in the related market.

Given the gap with other cities in the field of innovation and digital evolution, Brazil, in order to reduce it, has joined several initiatives dedicated to smart cities. For example, as a result of the development of revolutionary technologies, the city of Buzios has undergone a visceral transformation that has consecrated it as one of the 10 smartest cities in the way, thus inducing more than 100 municipalities to join the *Ciudades Digitales* program for evolve in the same direction and to benefit from new equipment.

Our research began by examining 100 Brazilian cities, identifying all the initiatives they could have.

It has contributed to the evolution of cities in order to digitize city services and improve citizens' quality of life. Starting from the identification of 200 projects, a skimming operation led us to select 50, on each of which the taxonomy proposed by Perboli et al. (2014) has been applied. Following a brief description of the projects taken as a sample, we have grouped the results of the individual analysis to highlight the elements on which the country focuses most to solve the main problems of urban areas and to start the innovation process of cities.

3.3.1 Sample Description

1# - Innovation for sustainable mobility and energy efficiency (2014)

In 2014, in Curitiba, a collaboration between Swedish and Brazilian companies started a project with the aim of implementing a service that provides more intelligent solutions in the mobility sector. These solutions cover many fields, from sustainability to energy saving. Volvo and Saab have provided a platform for monitoring and sharing information; KTH and UTFPR universities carried out research work to test and adapt the concepts to the context of Curitiba, design the configuration of infrastructure systems, monitor operations, energy and emissions budgets and design scenarios for the upscaling of intelligent concepts and solutions. The goal was to become a model on an international level, managing to raise awareness of sustainability and energy waste. The project started in October 2014 with an expected duration of 33 months and included a total budget of 186,477 MSEK (in 2014, around € 18,000), most of which would have gone to understand the investment for Volvo’s technology demonstration.

2# - Programa Nacional de Estratégias para Cidades Inteligentes Sustentáveis (2019)

During the Smart City Business Brazil held in Sao Paulo in July 2019, Vitor Menezes, secretary for telecommunications and digital policies at the Ministry of science, technology, innovation and communications of Brazil, underlined the benefits that cities would derive from the implementation of technological solutions which would make cities smart. The use of innovation, communication and technological infrastructure promotes the well-being of the community on four fronts: social, environmental, cultural and economic. The initiatives presented during the congress concern CCTV cameras, facial recognition, agricultural surveillance, rainwater collection, electronic medical records and urban mobility. The project should start with the creation of the National Chamber of Smart Cities, since *"We can't talk about smart cities if we don't have connectivity. We must evolve so that we can have a structured plan on the whole national territory" (Vitor Meneze speech).*

3# - Wind Energy (2019)

In Latin America, renewable energy production has grown significantly in the last decade. The use of green technologies such as wind turbines and solar radiation continues to expand; countries like Brazil are in fact trying to improve energy safety and reduce carbon emissions. The Brazilian government's incentive program for alternative energy sources has played a leading role in moving the region towards renewable energy. The program offered independent energy producers twenty-year flexible energy purchase contracts (PPA) at attractive prices with the state control body Eletrobras. In addition, Brazil's largest development bank, BNDES (Banco Nacional de Desenvolvimento Economico e Social) has provided low-cost financing. In this context, wind farms are particularly important, as countries like Brazil try to reduce their strong dependence on water energy by replacing it with other energy sources. Wind energy is an ideal solution for integrating hydroelectric power plants, especially during the dry season, when wind production is generally at maximum.

4# - Digital Favelas (2013)

In 2010, in Rio de Janeiro, a large operations centre was inaugurated where images from over 1000 cameras scattered throughout the city arrive every day. The public administration and some partner companies have decided that this plant would be the centrepiece of a project that sees certain groups of children from 5 pilot favelas as protagonists. These children will be armed with smartphones, high-resolution mini-cameras and a kite. The camera, attached to the flight instrument, will allow you to photograph favelas from above, zooming in on critical elements, while your smartphone will allow you to remotely control your shots and videos. All

the data will then be transmitted to the power station, to obtain a digital and detailed map of the areas overflown, to identify areas subject to hydrogeological instability, dangerous buildings, the presence of garbage and disease outbreaks, routes considered dangerous for armed and criminal gangs, places of historical interest and much more.

5# - City Operations Centre (2010)

In anticipation of the 2014 FIFA World Cup and the 2016 Olympic Games, the mayor of Rio, Eduardo Paes, commissioned IBM in 2010 to build a command centre capable of monitoring what is happening in the city. The centre coordinates the activities of over 300 municipal and state departments, as well as private and transport service companies, integrating them into a single digital command and control system. The aim of the project is to provide the city with an instrument capable of showing what is happening in the city in real time and then, through data analysis software, capable of predicting where traffic will flow, where it could occur accidents and when floods could occur. Citizens can receive messages with all updates on their mobile phones and can access cameras to see what is going on in the whole city.

6# - Planet SC / InLoop (2019)

A collaboration between the developer of affordable housing, Planet Smart City (Planet SC), and the real estate specialist InLoop will allow the construction of more than 2250 apartments in Sao Paulo. According to Planet SC, the country's housing deficit has reached 7.7 million units, making up 20% of the population living in inadequate housing. This is why the two companies have decided to provide the citizens of the Brazilian capital with a total of three projects which, starting from 2020, will integrate modern and functional design with intelligent solutions to offer residents a better quality of life. The development of Sao Paulo will therefore see the construction of apartments with intelligent solutions used in design and architecture, in technological systems, in the environment and in social innovation. This will allow residents, through the use of a free app, to manage energy consumption at home and to stay informed about local updates and community initiatives.

7# - Urban Futurability (2019)

Vila Olímpia, one of the main financial centres of Brazil but above all a model of the neighbourhood of the future, is the centre of Urban Futurability, a new Enel project. The heart of the initiative is the creation of a Network Digital Twin, the first in the whole South America: the *twin* is a three-dimensional digital model that faithfully replicates the local electrical infrastructure, from individual physical elements to the most complex dynamics of the its

functioning. Simulation is possible above all thanks to a network of about 5000 sensors installed on the physical network, which transmit real-time information on the status of the network to both the Distributor and the local stakeholders. The Vila Olímpia project will contribute to the protection of the environment by increasing energy efficiency and therefore reducing both greenhouse gas emissions and air pollution that grips large cities.

8# - Programa de Eficiência Energética (2017)

In Gravataì, through its Efficient Energy Program (PEE), the energy distributor Rio Grande Energia (RGE) is investing R $ 1.4 million to help reduce the electricity bill and give more quality of life to low-income families who live in the town. The project involves the donation and installation of 2,158 efficient showers equipped with heat exchangers to socially vulnerable neighbourhood residents. These showers are equipped with a mechanism that heats the water before it passes through the shower; in this way, the appliance needs less energy to heat the bathroom water. With the Efficient Energy Program, it is estimated that there will be savings of 3,452.8 MWh / year and a reduction in the emission of 461.98 tons of CO2 into the atmosphere. The energy saved by donating more efficient equipment to homes would be able to supply 17,264 homes for 30 days.

9# - Integração eletrônica transporte público (2012)

The search for urban mobility solutions is an urban development tool also in the Governador Valadares, established with the aim of integrating the different modes of transport and improving the accessibility of people in the municipality. More than R $ 97,000,000.00 will be invested in urban mobility by the municipal government of the Governador Valadares in collaboration with the federal government. These initiatives will concern, for example, road traffic with the creation of BRS corridors for the exclusive use of buses and emergency vehicles, accessibility for people with disabilities and reduced mobility, the restriction of areas and times of access and limited controlled circulation, the promotion of education for good traffic behaviour, the revitalization of horizontal and vertical signs, and the modernization of the entire traffic light system through the use of LED lights.

10# - Operação Caça vazamentos (2014)

The Caça vazamentos operation saves over 11 million litres of water per year in the municipal schools of the municipality of Suzano. The quantity that can be saved is the equivalent of the monthly requirement of 630 homes. This operation is conducted by the Administration, through the Department of Education, in the schools of the municipal education system to contain water discharges and promote student awareness. In addition to

the repair and maintenance of the hydraulic systems of the teaching units, part of the operation is also the replacement of conventional taps with intelligent equipment, with automatic spring, and the installation of tanks for collecting rainwater that can be used for the drains of the toilets, for cleaning the floors and for the maintenance of the gardens. The most impressive thing about saving over 11 million litres of water is that in the period between 2012 and 2013, the total number of students in the muni network increased by 9.8%. In other words, water consumption decreased by 31.14% in litres and savings in accounts were 28.59%, despite the growth in the number of students.

11# - Ônibus ecológicos (2014)

In the municipality of Suzano, in the state of Sao Paulo, a project has been started which envisages the delivery of modern buses for public transport with a new *Aria 32* system, which reduces polluting gas emissions. In addition to the environmental benefits thanks to the new buses, this project will include the installation of the Free Pass for students, new bus stops, new lines, accessibility, GPS and free wireless internet access. Within a few months, the project led to the delivery of 43 buses and the installation of 46 new stops, as well as a restructuring of the buses already in circulation.

12# - ZUP (2017)

Cascavel was the first city in the southern region to implement ZUP, a platform designed by TIM that allows more effective communication between the municipality and citizens. *"There are two ways to govern. One is to listen to the population and know the problems and the second is to deny and say that all is well. We opted for the first one, and this application gives us the opportunity to know our problems and give vent to solutions."* These are the words of Leonaldo Paranhos, mayor of Cascavel, during the official launch of the app. The application facilitates citizen participation in public management, allowing them to submit complaints or suggestions using the smartphone quickly and interactively. To this end, 170 different categories of services have been registered which will be automatically addressed to each specific secretary, who will be able to plan, execute, monitor and inspect the services provided. The citizen can also view all requests from the city and neighbourhood, using filters by date, category and geographical area, as well as checking the protocol and the progress of each of his requests.

13# - Intelligent praca (2017)

Paying attention to the safety of citizens, but also trying to improve the quality of their free time, the municipality of Paulista, in the state of Pernambuco, has launched an initiative

to strengthen the lighting of Praça Aníbal Fernandes. In particular, the Paulista Municipal Public Services Secretariat and the team of the public lighting management, with an investment of R $ 180 thousand, have started a program that foresees a reduction in energy consumption due to lighting, gradually reducing the number of lights on, according to the time slot, and the installation of 35 new lampposts and 23 reflectors, which allow better illumination of the sports fields in the square and of the points that once did not receive lighting. Local residents immediately noticed the change, feeling more confident about taking an evening stroll in the square. The project involved completing the works within a couple of months.

14# - Internet Social (2017)

The initiative was carried out in the municipality of Rio Branco, the capital of the state of Acre, with considerable appreciation from users. The project involved the installation of free Wi-Fi in some public places in the city, such as at the bus terminal and in Praça da Revolução. The connection does not provide for a maximum number of connected users, however there is a limit on the duration of the connection: 30 minutes, after which you must wait an hour before being able to connect again. To access the network, simply register with your e-mail address, full name and CPF (the equivalent of the Brazilian tax code). *"The goal of the municipality is to provide greater interactivity and communication between people"*, explains the director of Information Technology and the modernization of the management of the municipality, recalling that the program uses optical fibre, which guarantees greater quality, safety and speed in data communication.

15# - Parquímetro Street (2014)

Rio Branco was the first city in the northern Brazilian region to receive intelligent solar powered parking meters. These parking meters are equipped with panels that capture solar energy and allow up to twice the autonomy compared to traditional batteries, also obtaining significant energy savings. In addition, these tools allow you to organize parking spaces inside the parking lot, thus optimizing spaces and facilitating drivers' search for them. The parking meters are supplied by the Digicon company, which has delivered 65 parking meters to allow the organization of 1700 places in the central region and in the shopping centers of Rio Branco. The plant and the monitoring of the operation of the equipment were instead carried out by the company Serttel, winner of the offer. Overall, Digicon developed a business line targeting this market in 2003, providing a total of 3000 parking meters in 50 cities in 9 Brazilian states.

16# - Educação tempo integral (2016)

In 2016, in Curitiba, the mayor of Montes Carlos received the InovaCidade award, which is awarded to the best projects and initiatives that have contributed to improving people's quality of life. In particular, the municipality of Montes Carlos won the prize for full-time investments in the public education sector, managing to combine low cost and efficiency. *"They were simple solutions, with the same structure we had, without having to resort to imaginative projects. We extend school days, enhance the teacher, create non-school spaces, that is, quick, simple and effective attitudes. We cannot wait for funds and projects that will never come. We need to innovate, looking for practices that all serve at the lowest possible cost"*, explains the mayor. The commitment of the municipality is also evident in the investments made: in this initiative 28.50% of the total invested was invested, a percentage above the constitutional minimum established for that area (25%).

17# - Central de monitoramento (2012)

In 2012, the municipality of Maringá opened a competition with the intention of equipping the city with 80 cameras and an operational control centre capable of monitoring and monitoring what is happening on the streets. The chosen company was commissioned to supply and install equipment, materials and software licenses for video monitoring systems, which includes multi-service networks and image traffic infrastructures, to meet Maringá's needs. The package also includes training for up to 16 operators. The proposal consists in the installation of a system to obtain positive results in the fight against crime, emergency communications and constant surveillance in the points of great diffusion. The images captured by the cameras are transmitted to a monitoring centre which maintains a permanent connection with the environment. The system can therefore optimize public resources and increase the safety of the population. *"With the new centre, we will be able to identify people and license plates, assisting in road accidents, for example and also fighting cracks, vandalism, environmental crimes and many other illegal acts"*, explains the director of Social Defense, Rogério Mello.

18# - Parceria Samsung (2017)

The *Parceria Samsung* initiative promoted by the Municipality of São Paulo in 2017 aimed to replace the *Single Ticket*, as well as the traditional Smart Card for the control of city transport rates, with a digital system that allowed the user to pay subscriptions to public services via mobile devices. The completion of the project was facilitated by the partnership with the South Korean multinational *Samsung* which set out to test the payment methods of the bus fares made via mobile phone for free.

The project was in line with the city's tendency to move towards a *smarter conspiracy*. In fact, the increase in citizens' satisfaction following the digitization of a traditional service is one of the objectives that an intelligent city aims to achieve. Following the success of this project, the company extended the digitization process to all bureaucratic processes.

The result would be to offer citizens much safer services than traditional ones.

19# - FabLabs (2015)

In 2015, the government promoted the initiative to introduce FabLabs to facilitate the digital inclusion process, which has the aim of promoting access to ICT benefits to all people and groups of individuals who would risk being excluded.

In particular, the city of São Paulo set itself the goal of implementing 12 new FabLabs, as well as workshops that offer digital manufacturing services and that make it possible to develop three-dimensional objects and prototypes from digital designs through the use of avant-garde and equipment such as 3D printers and digital joinery.

The secretary of services, Simão Pedro, declared that São Paulo, by offering such structures in public places, would give citizens the opportunity to develop their ideas and small entrepreneurs to give shape to their projects. To make citizens independent in using these tools and equipment, the government made available to users of training courses that explained all the processes within these structures such as the production methods of the FabLabs and their tools, the development of customized products etc. The main objective of this project was to contribute to the creation of new products that solve urban problems.

In order to create and manage these laboratories, which provides for coordination of digital connectivity and convergence (CCCD), the secretary of services requested collaboration with non-profit organizations or entities.

20# - Contactless tags to bridge real and physical worlds (2012)

Contactless tags to bridge real and physical worlds project won the *Living Labs Global Awards 20*, competition for solving urban problems. With a view to hosting a large turnout of people due to events such as the World Cup and the Olympic and Paralympic Games of 2016, the government invested in this initiative to reshape the city's transportation system ensuring greater reliability.

The project, part of the *Rio Smart City* program, consisted of introducing smart stickers that offered access to the QR Code application and NFC (Near Field Communication - Communication by Proximity Field) technology. In particular, the user could obtain real-time information on the transport services (timetables, changes in routes, itineraries, points and

positions of the buses that circulate through the city) by simply placing the mobile phone in front of the tags.

The project for its realization included the collaboration of different figures such as that of the conservation secretary Marcus Belchior who was designated as responsible for the installation of the stickers, Franklin Coelho, secretary of Science and Technology and the president of RioÔnibus, Lélis Teixeira.

The latter, working with other transport companies who made their database available to app providers, focused on identifying an intelligent transport system.

The reduction of road traffic and the optimization of times thanks to the identification of alternative routes for reaching the destination are some of the benefits due to the introduction of this intelligent model.

Smart tags are an initiative aimed at being used by the population and visitors, allowing a new interactive communication channel.

21# - Free Wi-Fi (2015)

The Sinal Livel project plans to provide Brasilia's public areas with free Wi-Fi. Since the achievement of this objective required the development of wireless systems and the reinforcement of security, the project was supported by a consortium of four companies. For example, Mtel Tecnologia was responsible for building a MetroEthernet network, as well as a data centre consisting of redundant core switches, firewall security solutions, IPS, user authentication, web content filtering and a management platform.

The project leader, Alexandre de Oliveira Lobo, undersecretary for digital inclusion and technological content stated that *"following the project we included the possibility of transforming Brasilia into an intelligent city, with the interconnection of the systems and the possibility of using the technology in the areas of health, education, mobility and others"*.

22# - CIGE (Centro Integrado para Gestão de Emergências) (2016)

The objective of the CIGE project (2016) was to reduce crime on the streets of Salvador de Bahia and in the 13 cities of the metropolitan region.

The centre planned to use a building from which technicians could access different technologies, such as cameras, and different surveillance devices so that they could monitor the entire urban area. Intelligence Superintendency of the State, Public Security Secretariat (SSP), the Integrated Regional Command and Control Center (CCCR), worked together to build the facility.

But the essential element for the success of the CIGE is the use of cutting-edge technologies. Therefore, Technology, communication and intelligence cooperate to be able to create tools that would provide information on vehicles to the police force, so that they can intervene thus minimizing the number of thefts and increasing citizens' safety.

Clearly, the larger the area of cities controlled by the intelligent model, the greater the security of cities. In this regard, the government promoted partnerships with public and private institutions. For example, the partnership with Transalvador allowed the facility to use cameras to detect stolen vehicles in controlled areas. The biggest challenge was to create a collaboration with banks, shopping or with the *ViaBahia* dealership.

This project, funded mostly by *Banco do Brasil*, is similar to those successfully brought to other cities in the country such as SP RJ and BR.

23# - Luminárias inteligentes (2016)

Belo Horizonte is one of the smartest cities in Brazil. The government supported by other public / private institutions has carried out many initiatives to reshape the city in a more sustainable perspective. The *Luminárias inteligentes* project, managed by BH Lighting Public Consortium (BHIP), winner of the PPP launched by the Town Hall, consists in replacing the bulbs of the light poles with LED ones and creating an intelligent lighting network. The initiative provided that the new appliances could be managed remotely, so that their intensity could be managed by reducing consumption and costs for the city. Over time, the lighting system is expected to interact with the maintenance system and to create a Wi-Fi network.

24# - CCO (Centro de Controle Operacional) (2015)

In 2015, the municipality signed a partnership with the *Analysis, Research and Technological Innovation Center* (Fucapi) for the creation of a city monitoring centre.

In particular, the project envisaged creating and using new technologies that, through data collection, would provide information on infrastructure online.

For example, spreading pressure gauges in cities would allow storms and related areas subject to risk to be predicted so that the authorities can take the time to intervene and safeguard citizens. The new instruments and sensors would be used to monitor various phenomena, such as road congestion.

25# - ICI (Instituto das Cidades Inteligentes) (2015)

ICI (Instituto das Cidades Inteligentes) is an organization that operates non-profit in the Brazilian territory, providing the necessary technologies and tools in order to transform cities into smart cities.

ICI in practice has improved and revolutionized the world of Information Technology (IT) by developing and managing innovative products that improve the performance of urban services.

Public administrators who contribute to the transformation of management to achieve sustainable economic growth and improve the quality of life of citizens contribute to this development and implementation of ICT. Furthermore, the profits associated with technological innovations are invested in new projects in order to find new solutions to urban problems.

The transformation of the city of Curitiba is a striking example of the efficiency of the ICI. Although there are numerous projects proposed by the institute (digitization of city services, the inclusion of Internet access points for the population, etc.), the launch of the product line marked a considerable development of management services. The organization has created a complete line of ICT solutions for public management that aimed to guarantee the satisfaction of the public manager and the citizen, offering greater efficiency, modernity, agility, integration, transparency and economy to Brazilian municipalities.

The success of this institute is evidenced by numerous awards, the most recent being the Paraná Management Quality Award (PPrQG). Bronze plaque level II - 250 points in 2017.

ICI currently has eleven customers but plans to increase their number in the coming years.

26# - Bicicletário (2012)

Bicicletaro led to the installation of 10 bike sharing stations between the neighbourhoods of Recife, Santo Amaro and Santo Antônio.

This initiative offered citizens an alternative to more sustainable and innovative transport systems.

The prefect João da Costa declared that *"Essa parceria com o Porto Digital representa um passo a mais que damos para consolidar um novo modal de transporte na cidade. [..] Isso facilitará o deslocamento das pessoas entre diversos pontos da cidade, com a utilização dessas bicicletas, de forma prática, saudável e sustentável"*.

The service provided that each bicycle was equipped with an intelligent self-service mechanism, which blocked the means of transport with an electronic system, and which could be unlocked through the use of mobile phones. However, to use the service, the user first had to register on the website and pay the monthly fee of R$ 10.

27# - Playtown Recife (2015)

PlayTown Recife is the first initiative by the government to increase tourism.

The project launched in 2015 after the consolidation of the partnership between the City of Recife and the Ministry of Tourism, envisaged the installation of *smart* urban furniture in

the major points of interest in the city. in particular, these tools would be able to interact with tourists and citizens by providing them with information and curiosities about the main monuments and attractions located near the place where the furniture was placed.

PlayTown Recife is an unprecedented project that aims to create new tourist equipment that will make life easier for citizens and tourists.

28# - Projeto bicicletas comparitilhada (2016)

Similar to the *Bicicletario* project carried out in the city of Recife, the *Projeto bicicletas comparitilhada* focuses on the introduction of an alternative transport system to motor vehicles. More specifically, the collaboration between Belém City Hall and Hapvida Saúde led to the installation of 11 Bike Sharing stations in the city of Belem.

The implementation of this sustainable transport model was highly appreciated by the citizens of Belem as it was considered as a healthy solution to move around the city that encouraged them to take care of their bodies, thus abandoning sedentary life, but at the same time contributing to make the environment less polluted. In fact, the introduction of the Bike sharing service significantly reduced the number of vehicles on the streets.

29# - Transforma Recife (2015)

Transforma Recife led to the creation of the first digital volunteering platform in Brazil. The project is mainly based on two axes:

- the technological axis, being a digital platform where social organizations can register and offer vacancies for a social commitment;
- the axis of human connections, since many people are united to act for the common cause of wanting to help the neediest.

In practice, the system requires that volunteers make a registration by entering preferences for performance, location, timing and ideal cause. At the same time, the various organizations also register and fill vacant positions, informing them of the need to expand the job.

After collecting the various information, the platform connects the volunteers with the most compliant institutions through a cross-check of the data.

Through Trasforma Recife, anyone on their home computer can choose the role, entity, day and time when they want to donate their workforce. Clearly a platform of this magnitude saw the participation of several partners.

30# - Cidade Cognitiva (2013)

Cognitive Cidade is a project put forward by the government and IBM Brasil to develop the cities of Porto Alegre into a cognitive city.

The promoters of the initiative showed that the transformation into an intelligent city would imply substantial changes in the structure of the city. in particular, we would witness the digitization of services and the introduction of new equipment and technologies that would offer more sustainable solutions to urban problems. The end result would be an indisputable increase in the quality of life of citizens and greater protection of the environment.

In emphasizing the need for this evolution, the prefect defined the project as *"Uma ferramenta única no mundo que irá nos ajudar na melhoria da tomada de decisões sobre as obras e ações demandadas pelo Orçamento Participativo."*

Clearly, the change of the city into *Cognitive Cidade* would require high costs and therefore large investments in the technological sector. Therefore, the government is also financially supported by private organizations.

31# - POA Digital (2015)

POADigital focuses on the evolution of the city through the development of new start-ups.

The government and IBM with the use of Big Blue's Bluemix technology, created a portal that provided a dynamic environment where start-ups could grow, communicate and collaborate with each other.

The cities opened the municipal data to start-ups because they believed that this project could lead to the development of ideas and equipment that would improve the quality of life of citizens and that would solve the main urban problems.

In addition, the program also facilitated companies that could take advantage of various support programs for free, such as software in a test environment or Cloud For Startup.

IBM, the project's main funder, released credits of up to $ 120,000 so that start-ups could use their Cloud solutions.

32# - Cittamobi (2014)

As already emerged from the previously treated projects, the central problem of Brazilian cities is the road congestion and the noise pollution. In order to find a solution, Cittamobi aims to reinvent public transport through a platform that allows citizens to interact with cities.

The system transmits real-time traffic information to users and also recommends the best alternative route to follow to optimize their time. Moreover, Cittamobi differs from other apps on public transportation, since it gives its users the opportunity to express themselves and

leave feedback on the means used so that companies and municipalities can make improvements on vehicles.

The application also combined with the 118 service has facilitated the identification and resolution of problems and road accidents. The growth of users who use the device testifies to the efficiency of Cittamobi and encourages citizens to use public transport and abandon their motor vehicle.

33# - Ecoponto (2017)

The municipality through the Municipal Superintendency of Sustainable Development (Sudes) managed to install three *Ecopontos* in the city of Maceió (AJ).

The new public structures have favoured the regularization of waste disposal in the capital and therefore also the reduction of dirt and the accumulation of garbage on the streets. More in detail, each structure is equipped with three containers in which waste is deposited, and which are emptied daily in the city landfill. In this way, the city guarantees organized disposal that does not harm the environment or public health.

In addition, Sudes encouraged employees who worked in the vicinity of some of the aforementioned structures to register to increase the number of people using the eco-pontos, by paying a fee. For example, the 50 registered at the Pajuçara Ecopunto received a basic food basket monthly after completing 50 trips.

34# - Parque Tecnológico (2017)

The Municipality of Campo Grande, in collaboration with the Mato Grosso do Sul State University (UEMS), promoted the creation of a technological park.

The park is a platform that puts entrepreneurs in contact with various companies so that these entities can exchange information, knowledge and encourage the formation of new companies. Therefore, in addition to improving the infrastructure and services of the cities, the project would generate new companies and therefore also new jobs for citizens.

However, the initiative provides for high initial costs due to the development of new technologies and new equipment. To this end, the municipality has signed partnerships with companies also outside of Brazil in order to achieve sufficient investment for its realization.

35# - Projeto Cidade Digital E Projeto Conecta (2014)

The city of San Bernardo do Campo in recent years has improved the city's network to the point of boasting one of the country's largest and most efficient ski lifts.

The infrastructure of the high-speed communication network and the ability to transmit data and voice, called the Digital City Project, has allowed the integration of administration

and public equipment. All systems for administrative use are shared among employees, centralized in the data centre and protected by security systems. In addition, SBC's fibre optic network has simplified communal services allowing the citizen to solve many of the problems via the Web and thus saving them time.

In addition, the network adapts to the dynamic structure of the municipality which implies that there is a connection between different administrative units, which are constantly increasing.

Examples of projects created thanks to the use of the network are:

- *Conecta*: an initiative of the Department of Education which involved restructuring the administration of the secretariat and municipal schools. Access to the wireless network gave students the opportunity to learn in a more interactive way through the use of laptops;
- *Safe City*: an initiative that envisaged increasing the security of cities by monitoring a network of cameras.

The evolution of this network on which the government has invested heavily has seen significant improvements in the lives of the inhabitants of San Bernardo in various sectors. Therefore, the municipality plans to continue investing money.

36# - SmartSantander (2017)

City Cooperation Center (CCC) is the initiative proposed by the mayor of the city of João Pessoa that would help transform the city into a smart city. The project is inspired by the SmartSantander structure that has made the Spanish city a world reference in technology and urban planning experiences.

In particular, the Santander monitoring centre has allowed researchers and scholars to have access to the various data collected by sensors scattered throughout the city to improve services and ensure more efficient coordination of actions in the field of mobility, citizens' safety, natural disaster prevention, urban planning.

In fact, sensors transmitting information on traffic, the environment and climate would allow citizens and authorities to take preventive action and take the necessary measures.

Central themes of the project are the reduction of road congestion and accident response times and the improvement of public safety and the ability to respond to natural disasters. In this regard, the city would modernize and bring a solution to the main urban problems.

37# - Estação Digital Móvel (2013)

Estação Digital Móvel promotes the phenomenon of digital inclusion, or offers access to digital devices to those who do not have the possibility to use them.

In particular, the government released buses equipped with computers with Internet access, which could be used by the entire population. The users of the service, after prior registration, could choose to simply use the equipment or had the opportunity to attend courses on fundamental information technology and seminars on e-government and social media for free. A year after the launch of this initiative, the municipality registered a significant increase in participants, many of whom had never had the opportunity to use a computer.

This project can be categorized among the initiatives that focus on the social sphere since it gave the opportunity to learn how to use IT tools to those who until then could not afford it economically, giving it even greater employment prospects. A further consequence of this initiative is the reduction of crime in the streets as young people find themselves busy taking courses and taking their time in the structures and no longer in the streets.

38# - Programa Municipios eficientes (2009)

the Rio de Janeiro State Planning and Management Secretariat - SEPLAG promoted the *Municipios Eficientes* program to try to redesign the structure of the municipalities and improve their management. The project saw the collaboration of the Municipality with AEMERJ, which contributed in choosing the technical criteria for selecting the municipalities to be developed, and with PRODERJ, technical manager who presented the e-city software as a tool for managing the main areas of the municipalities. Although the government was promoted by the government, financial resources were decentralized between SEPLAG and PRODERJ

The project was divided into two phases:

- Pilot phase: in which the software was implemented on four pilot municipalities. In particular, the Areal, Armação de Búzios and Valença system managed education while the Araruama system handled taxes;
- Expansion phase: implementation of the system on the municipalities that comply with the technical selection criteria defined by SEPLAG and AEMERJ.

The project aimed to provide municipalities with useful information for analysis and decision-making in the tax and education sector, thus ensuring maximum transparency. The main objective was for each municipality to manage itself in a self-sufficient way.

39# - IoT (2009)

Government and Ericsson collaborate on the creation of the first IoT Hub for public safety in the city of São José dos Campos. The partnership, supported by startups, institutions, companies and universities, has led to the development of software for smart cities.

Ericsson is a company that over the years has focused on digitization and has therefore invested in many projects focused on IoT and 5G. these technologies were considered as key

elements to make cities evolve, since they put humans and machines in communication and also transmit precise information on services, thus guaranteeing greater control in the management of activities. Over the years the city has adhered to many of the initiatives proposed by the company such as the use of the control and monitoring system supported by about 500 cameras or the introduction of climate sensors that measure temperature, humidity and CO^2 levels, in addition to the introduction a public Wi-Fi network and a public lighting system (Ericsson Smart Lightning).

In order to develop more intelligent models, the company created the Connected Society laboratory, which promotes the testing of new Internet of Things technologies in social projects focused on intelligent water, agriculture, forest protection for prevention and disaster monitoring.

40# - Polo Digital (2009)

the town hall entered into a partnership with the Neobpo Casa company in order to create a digital hub with the aim of improving the education sector. The project involved inserting computer labs within the schools, each of them with 15 devices, so as to be able to increase the quality of teaching. Like the *Estação Digital Móvel* project, the *Polo Digital* can also be catalogued among the social projects since it promotes the digital inclusion process, thus giving students greater qualifications for entering the job market.

41# - Catador Digital (2017)

Digital Scavenger offers a sustainable solution for the disposal of electronic waste.

The program plans to train those involved in waste collection, teaching them to recondition and reuse electronic equipment. In this regard, the devices discarded by people would be reconditioned and then sold at popular prices and in the event that a repair is not possible, the pieces would be used for works of art and decoration.

In this way the promoters of the project, the Municipality of Jaboatão dos Guararapes and Seja Digital, aim to reduce the environmental impact by minimizing waste and at the same time promoting the local economy.

42# - Uso inteligente de agua (2016)

Over the years, the city of Sorocaba has carried out various initiatives that aimed to use water intelligently. water is one of the essential elements for the life of man and the planet and in recent years, due to the pollution of global warming and excessive waste, it is running out. In this regard, the city has achieved remarkable goals in the clean-up of the waters of the Sorocaba river and the creation of the linear park, which has given citizens space for leisure

and sport. As a result of these plans, the city was recognized as one of the five smartest cities, among developing countries, in relation to the use of water.

These projects, promoted and financed by the government, have a great sustainable impact and have improved the quality of life of its inhabitants to the point of encouraging other cities to invest in similar initiatives.

43# - Monitoramento no parque da biodiversidade (2015)

The city of Sorocaba is one of the Brazilian cities that is moving fast towards a smarter configuration. In addition to various initiatives focused on the use of intelligent models to protect the environment, in 2015 the government and the Toyota do Brasil company entered into a partnership to increase the safety of the Parque from biodiversidade. The new security system, offered by the multinational, consisted of two PTZ cameras and nine internal cameras for monitoring the park buildings, also equipped with audible alarms. At the entrance, moreover, the electronic equipment allowed the identification of each visitor thanks to the prior registration which included the insertion of a personal photo so as to facilitate the control and identification of the customers.

44# - Maior sala de aula do mundo (2015)

By signing the agreement with one of the most innovative companies in the technological field (Cisco do Brasil), the municipality of Sorocaba contributes to making the city more digital, more entrepreneurial and more informative.

By joining the Cisco Networking Academy-NetAcad educational program, Sarocaba gives thousands of inhabitants the opportunity to participate in the courses offered by the company on digital inclusion, information technology, entrepreneurship and IoT. The topics dealt with are now the basis of modern society which increasingly points towards digitization and innovation and their knowledge is a prerequisite for entering the job market. Therefore, the participants in the courses, by gaining skills in the IT field, would be able to obtain greater employment and earning opportunities. The IoT course is the one that is oriented towards a future dimension. In fact, the teachers prepare the students for the near transformation of the cities where the machines, the technological devices will be able to interact autonomously and would be able to communicate information to men through the use of specific devices.

45# - Conecta Cuiuabá - WiFi escolas (2017)

Net Escola is the branch of the *Connecta Curitiba* project, which plans to modernize the world of education thanks to free internet access. The group of America Movil, cooperating

with the municipal education centre of the city of Curitiba, made available to 82 school facilities, two points of access to the broadband Wi-Fi network and two points of cable TV with HD signal.

In addition, the Net company (part of the *America Movil* group) and the institute *Crescer ea Secretaria de Municipal de Educacão* offered training to teachers so that they could learn how to use the new educational tools efficiently to ensure the highest quality of teaching for teachers. own students.

46# - Extreme Networds Caxias do Sul (2016)

In 2016 Caixa do Sul transformed the city's telecommunication network thanks to the improvements made by Extreme Networks. The implementation of 126 km of optical fibre allowed the creation of a fully integrated network where more than 200 administrative units could interact with each other.

Quality, efficiency, speed and safety are some of the adjectives that describe the new system. For example, in the event of equipment failure, the system is able to identify the problem, even if it is due to a lack of electricity or a cable break due to external factors. The result would be an optimization of time and quality. this tool was used in various areas such as healthcare to offer a higher quality service. in this regard, the modernized servers in primary healthcare facilities would have become able to update in real time all the procedures performed on patients.

In conclusion, this system is expected to be implemented in all areas, thus digitizing services and improving efficiency.

47# - Laboratorio Digital (2016)

The city Campina Grande, tired of being dependent on the traffic light manufacturers, decided to produce its own light signalling equipment. In this regard, the superintendency of public transport in collaboration with the Universidade federal de Campina Grande created a digital laboratory that would allow the creation of traffic lights with a higher quality than those commonly sold. In fact, the equipment was made with twice as many LED bulbs in order to increase the signalling quality and make the roads safer.

This project was economically viable, as the city managed to cut costs by 50% while guaranteeing the creation of products with greater quality and efficiency.

48# - Sistema de Videomonitoramento (2014)

The central theme of the project is security in the city of Jundiaì. In order to reduce street crime, the government strengthened the city monitoring system used by the Guarda

Municipal. The use of the OCR camera system allowed the authorities to be able to trace more cars and therefore to recover many stolen vehicles and track more fugitives. However, there was an increase in crimes in school facilities and therefore public institutions showed the need to continue investing in the project to secure all areas of the city thus improving the local police force.

49# - CCO (Centro de Gestão e Controle Operacional) (2014)

In 2015, Curitiba transformed the Urbs operational control centre into a *Centro de Gestão e Controle Operacional*. The new structure, having free access to the 1024 cameras installed in the city, offered a city monitoring system and communication with the police force in order to increase safety on the streets. The new Center includes the collaboration of an online command group, technicians, engineers and traffic inspectors, public transport and taxis, as well as municipal guards. For example, as regards the public transport sector, the CCO receives information from the electronic ticketing system so that it can know in real time the position of each bus, the speeds with which it travels, the number of passengers who have passed through the turnstiles, how many are exempt, how many are paid by card or cash and what is the situation of the bus at that moment. In addition, by means of a GPS system, bus drivers inform the centre of breakdowns, accidents and possible problems so that passengers receive instructions on how to proceed.

The efficient functioning of the new structure required developments of new technologies that guarantee an interaction between the different operational areas.

50# - Programa Inovação (2017)

The municipality of Anápolis has promoted the *Programa Inovação* which aims to optimize the processing time of the services and to reduce the response time of the municipality in the most diverse areas. More in detail, the promoters of the project created the *Portal do Cidadão* which allows online execution of the procedures for the issue of building permits, guides and certificates, including land use. The platform has simplified the traditionally long bureaucratic processes thus encouraging entrepreneurs, who in the past have had difficulty selling structures, to invest again in the sector.

Both the economy for the management of public money and the population benefited from this modernization.

3.3.2 Taxonomy Results

This subparagraph summarized the results of the analysis of each SCPs to highlight the elements on which the country focuses most to solve the main problems of urban areas and to start the innovation process of cities. The process of analysis can be displayed in the *Appendices*.

Description

As previously clarified, this axis allows you to define the context in which the SCPs are framed and the area on which they focus.

The following sub-paragraphs illustrate, in particular, the results obtained from the analysis of each subcategory related to this axis.

The full analysis is available in *Appendix A*.

Objectives

The analysis of the fifty *Smart City* initiatives, to which Brazilian municipalities joined between 2012 and 2019, revealed that each of these SCPs can be qualified as a *multiple-objective project*, that is, as a project that produces benefits in multiple areas simultaneously. In particular, the eight main objectives at the centre of the projects are: Water, E-Governance, Buildings, CO2 Emission, Energy, Security, Social Innovation and Transportation.

Most of the projects (68%) focus on *Social Innovation*. This circumstance is not surprising if we think about the social context in which these initiatives are carried out and which allows us to have a clear understanding of the problems that cities, by endowing themselves with projects, intend to remedy.

The Brazilian context is that of a country characterized by a large population, most of which, however, does not have the necessary means to support the costs of education and education, because it lives in conditions of extreme poverty. Specifically, the *Instituto Brasileiro de Geografia e Estatística (IBGE)* has disclosed the alarming fact that more than 7% of the Brazilian population (which corresponds to approximately 15,340,740,125 inhabitants) is illiterate. A direct consequence of this reality is that, although Brazil is out of recession, the labour market remains very weak with unemployment above 13%, making it particularly difficult for the poorest and least educated to find work. In addition, the lack of work also increases another of the country's main problems, namely the crime rate, which currently stands at 80.47% and which the government expects will increase in the next 3 years. Cities then invest in social innovation to improve citizens' quality of life. To this end, they try to strengthen the digital inclusion process, giving the less fortunate the opportunity to acquire

new skills in the technological and digital field, so as to have more opportunities to find employment.

For example, the city of João Pessoa, creating the digital bus with the *Estação Digital Móvel* program, gave many students the opportunity to learn how to use basic computer systems and, at the same time, reduced the number of children for roads, thus also reducing crime. Since the latter is a major concern for the country, *Security* 36% of the projects focus on improving the lives of citizens through a reduction in crime. To this end, many of these initiatives envisage the strengthening of city monitoring systems through new technological devices.

Cities have also invested heavily in projects that aim to use sustainable forms of *Energy* (42%) and reduce *CO2 Emissions* (42%). As for energy production, Brazil has natural resources that are among the cleanest in the world: in fact, thanks to the vastness of the territory, 81.7% of the country's energy production capacity comes from sources renewable (for example, 68.1% of Brazil's electricity is produced from hydroelectric energy alone).

Through the SCPs and the various infrastructure programs, cities expect that renewable sources will represent around 82% of the Brazilian energy matrix, while other renewable energy sources will reach around 30%.

As regards the issue of reducing CO2 emissions, it is also central since Brazil, in the past, has been considered one of the worst performing states in terms of environmental conservation, ranking seventh in the ranking of the countries that generate the greater quantities of greenhouse gases. Following this ranking, the country committed itself to carrying out many projects aimed at safeguarding the environment, becoming the first large developing country to take on a commitment of this magnitude.

This issue is closely linked to the need to improve the urban transport system. For this reason, 36% of SCPs offer sustainable solutions for *Transport* systems that are alternative to traditional ones. In addition, cities have invested in improving public services to encourage citizens to abandon private cars, so as to reduce road congestion and air and noise pollution.

The analysis conducted on the projects shows that those that deal with the object of *E-Governance* (34%) have led to the creation of technologies that have significantly improved efficiency, transparency and communication in relations between government, public administration and citizens.

Finally, *Buildings* and *Water* are the objects that have been least treated in the projects sampled. However, they are both issues on which cities plan to focus in the near future in order to improve their performance.

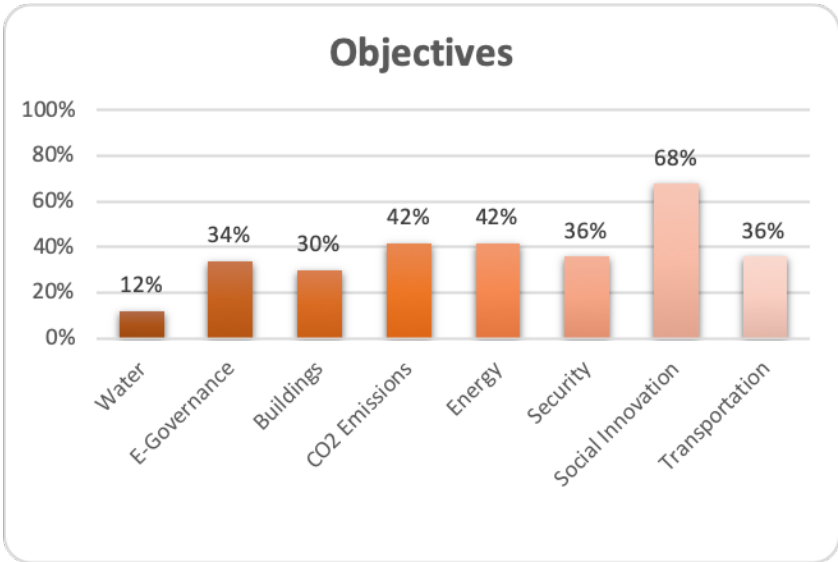


Figure 27 - Objectives

Tools

The transformation of a city in an intelligent sense requires a digitization process that occurs through the implementation of revolutionary technological devices. Therefore, as confirmed by all studies, technology is characterized by being the central element for the realization of a Smart City.

The taxonomy previously analysed identifies nine tools that are provided for these specific purposes in the SCPs: Cloud Computing, Database, Decision Support System, Information and Communication Technology, Innovative Sensor, Legal and Financial Instruments, Other New Technologies, Smart Devices and Smart Grids.

Among these, our analysis finds that *Information and Communication Technology (ICT)* is the solely tool used in all the SCPs sampled. The circumstance is not surprising from the moment in which this infrastructure is the basis of the formation of a Smart City since it manages urban flows and transmits information in real time which improves the quality of life of the inhabitants.

The benefits of implementing ICT are such that scholars of the past believed that it was enough for cities to use ICT technologies to be classified as *Digital Cities* or *Smart Cities*. However, this belief was disproved and the aforementioned technologies were defined as necessary but not guaranteed to transform cities into SC.

As for the specific case of Brazil, until 2011 the Brazilian industry is mostly focused on the agricultural and oil sector: it is the same year, in fact, the statement by the Minister for Science and Technology that denounce the weakness of the Brazilian industry in the field of innovation. Since that time the country has reversed the trend and has invested heavily in the branch of R&D technology to try to reduce the gap with other cities in this area, by joining

various initiatives aimed at digitizing cities and creating the ideal environment for the birth of new SC. Following the implementation in the processes of the new infrastructure, the Brazilian cities managed to reduce both the information of others and the price of the output, at the same time increasing the quality of the products.

Another tool used for the realization of the SCPs is *Other New Technologies* (84%). *Other new technologies* means all the equipment and tools designed to solve urban problems and to improve traditional services, increasing their efficiency and quality. An example is the QR Code technology used in the *Rio Smart City* SCP to make the public transport system more reliable and to encourage residents and tourists to move around urban areas with buses.

The Figure 28 shows that 64% of projects requires the use of the *Database*. The collection of data on the urban environment and its services allows you to document and transmit information on cities in real time, so that you can identify the main problems of citizens and remedy them. Brazilian cities, for example, have succeeded in reducing road congestion through devices that make traffic data and information on alternative routes available to citizens in real time to optimize time.

As it is shown in the figure below, *Cloud Computing* is used in 48% of SCPs. This tool facilitates the formation of start-ups and new companies and contributes to the transformation and expansion of existing ones. The Brazilian cities have signed partnerships with companies specialized in the sector (IBM, Huawei, etc), which give participants the opportunity to take advantage of the services offered on demand through the Internet, each of which specializes in different networks (security, data migration, management etc).

The Figure 28 also reveals that the 40% of the projects taken as a sample envisage the use of *Portable Devices*, referring with this expression to the electronic equipment that are connected to other devices. The reported data about a widespread use of such equipment appeared indeed lower than our expectations, since this tool allows citizens both to interact with other users and to interact with other tools. The reason for the low mass use is due to the fact that many cities are very backward from an innovation point of view and the respective inhabitants cannot afford the purchase of such devices. Therefore, cities have given priority to new or necessary equipment for their evolution.

The analysis also identifies the least adopted tools: the *Innovative Sensors* (34%), *Legal and Financial Tools* (22%), *DSS* (16%) and *Smart Grids* (20%).

The lesser use is due to the fact that the selected projects cover a time span from 2012 to 2019. Well, as previously anticipated, until 2011 Brazil had not yet become part of a digitalized world therefore, it first invested in tools necessary to start the evolution process, focusing on the technologies listed above only more recently (as the same data allow to obtain) and therefore expecting that the percentages relating to the use of the same will increase.

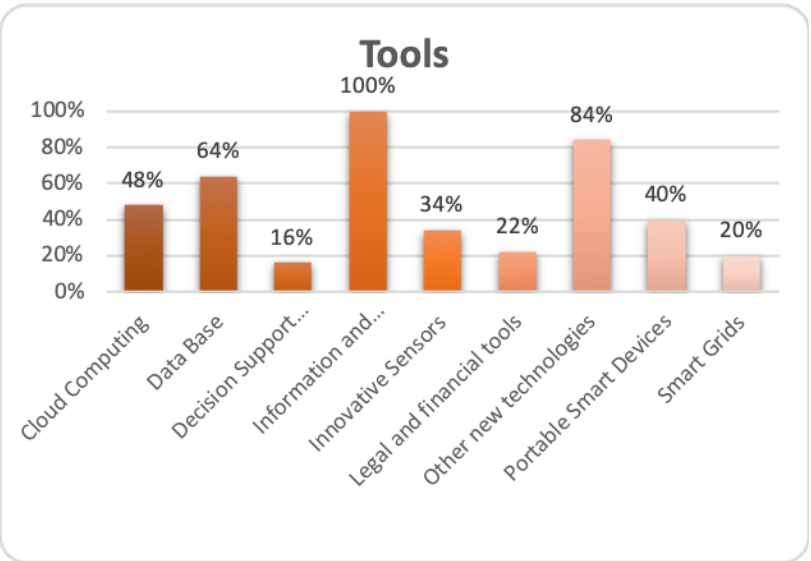


Figure 28 - Tools

Project initiator

SCPs are initiatives promoted by public or private entities in order to obtain benefits.

Private and public initiators are motivated by different motivations: on the one hand, public entities aim to improve the quality of life of citizens and the performance of cities; on the other, the goal of private companies is to increase profits and become more competitive in the market.

The data obtained from the conducted analysis show that the 68% of the SCPs are promoted by *public* institutions, the 26% by the collaboration of *public and private* entities, while only 6% is attributable to *private* companies.

The reason is due to the fact that the country experienced a deep economic recession between 2014 and 2016 such as to downgrade the country to the level of *non-investment*. Therefore, governments and municipalities found themselves promoting and investing in initiatives focused on the development of Smart Cities to try to modernize cities by making them more attractive for investments so as to be able to emerge from the economic crisis that afflicted them.

The participation of private entities was justified by the belief that, confident of the imminent recovery of the country, they would have benefited economically from strengthening the image of the company which would then be associated with the evolution of cities in SC.

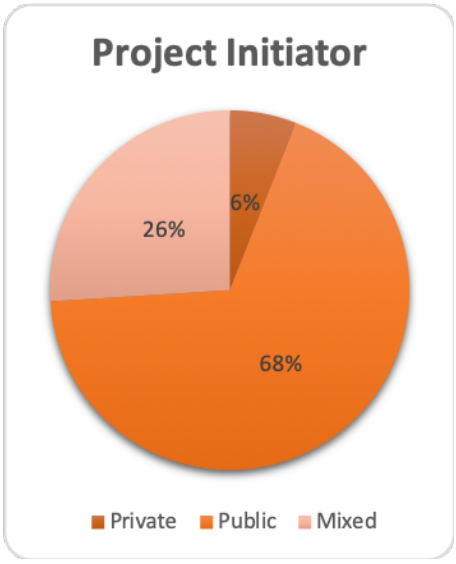


Figure 29 - Project Initiator

Stakeholders

The sub-category of Stakeholders identifies the figures involved within the projects: it therefore refers to people, organizations or entities who perceive the variations connected to the realization of a project and who at the same time with their actions can influence the results.

As these are initiatives undertaken for the creation of Smart Cities and therefore aimed at digitizing cities to remedy urban problems and increase liveability, *cities* and *citizens* are parties involved in all the projects examined (100%).

The *public administration* follows, which is involved in 94% of the projects sampled.

As previously clarified, most of the SCPs have been promoted by the government to revive the country's economic situation and become more competitive in the world market. public institutions are both initiators and financiers of many projects therefore their participation is necessary for the launch of the initiatives.

Universities, on the other hand, are the institutions that appear to have participated less in these projects (16%) since in the years in which the initiatives were launched, there were few universities in the country that had an innovative R&D area (such as USP) available which allowed him to actively participate in the initiatives. However, this situation is changing to the extent that some Brazilian universities today occupy excellent positions in the world ranking.

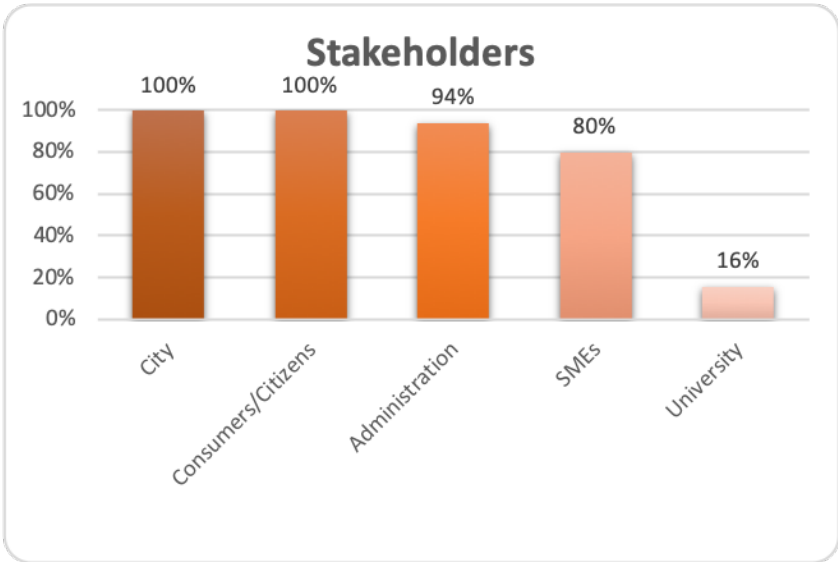


Figure 30 - Stakeholders

Business Model

As explained in the previous chapter, the Business Model identifies the entity that manages a project and those who provide the resources necessary to achieve the purpose (financial and infrastructural).

The analysis carried out on a sample of 50 projects can be taken as a model to illustrate the Brazilian situation, since a considerable number of projects that have been carried out in recent years in the South American state are taken into consideration.

In the next paragraphs we will go into detail on the individual components of this dimension, to define what is the trend that drives Smart City Projects in Brazil.

The full analysis is available in *Appendix B*.

Management

The Management represents the figure, from a single person to a group of companies, which coordinates, organizes and has control of every activity and aspect of a project; in other words, it is the figure who manages the project.

In our analysis of the Brazilian situation, it is immediately evident that most of the projects have been managed, or are managed, by *public* institutions. In fact, it is noted that 62% of the projects were managed by institutions of public nature. Governments, Ministries and municipalities, as well as universities, in addition to be the main promoters, are also the main managers of the projects and they take care of their success. The Figure 31 shows that 62% of public institutions far outweigh 6% of projects managed by *private* entities, while the remaining 32% is made up of partnerships between *private companies and public institutions*.

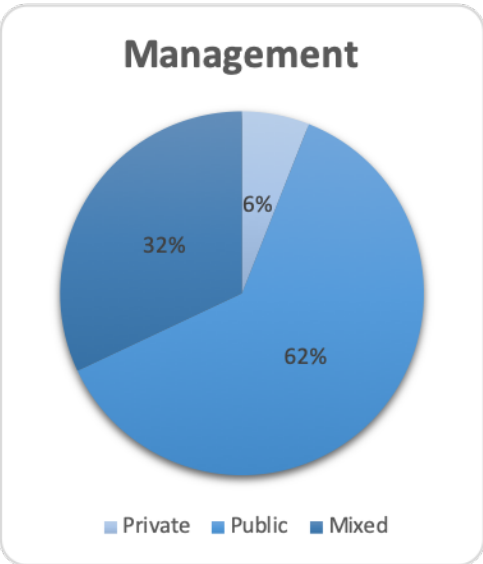


Figure 31 - Management

Now we will try to explain why in Brazil there is a prevalence of SCPs managed by public institutions.

Since the 1990s, Brazil has grown at a fast pace thanks to the expansion of the formal sector, the workforce and foreign demand, especially of raw materials. The growth and social policies implemented by governments have favoured the impressive result of halving the poverty rate and significantly reducing social disparities. However, starting from 2012, the favourable conditions that had promoted their progress disappeared, the structural knots of the Brazilian economy returned to the surface: stagnant productivity and the modest degree of connection with the rest of the world slowed down development, made it difficult to finance the growing social spending and led to a progressive worsening in public finances. The Petrobras scandal, which erupted in 2014, and the subsequent political crisis have further curbed the economy leading to the deepest recession of the last forty years in the two-year period 2015-2016.

Because of this situation, the main figures that try to raise the economic condition, and therefore the quality of life of the citizens, are the local municipalities, administrations and universities.

Infrastructure financing

Notwithstanding the foregoing, the provision of infrastructure mainly comes from private entities. The companies that cooperate in the SCP are usually leading companies in the reference sector, and this allows them to supply equipment, instruments and services such as installation and maintenance with a low risk coefficient. Thanks to economies of scale, these

companies, by increasing their production batches, can reduce unit costs, and for this reason investing in SCP allows them to amortize the risk rate.

More specifically, 72% of the infrastructure supply comes from *private* companies, while 56% from *public* institutions. The result is more than 100% because in some projects there is a partnership between private and public regarding the financing in the form of instruments, as well as for management.

This form of financing is configured by equipping the cities, or nations, with the equipment necessary for the planned activities: water systems, solar panels, ecological buses, control operations centres and buses equipped with computers are just some examples. As previously mentioned, the supply of infrastructures also entails the provision of those services directly connected to the instruments in question. Companies that invest in infrastructure will therefore be required to provide services such as installation, maintenance and all the series of services necessary for the proper functioning of the infrastructure.

Financial resources

With regards to financial resources, the situation is the opposite. The 94% of the projects were financed economically by *public* institutions, which made available to the project funds that could receive a different destination. However, only 50% of the projects received financial resources from *private* companies. As well as for infrastructure financing, the result is greater than 100% because some projects are subject to collaborations between private and public entities

As already explained about the Management, public institutions are the first supporters of projects that bring benefits to the community, in particular in countries where these benefits are generally in short supply. In our case, ministries, municipal administrations or the government itself allocate part of the public funds to the implementation of projects that guarantee significant benefits for the whole community.

Purpose

Let's now analyse the last axis of the taxonomy based on the results obtained from the sample of 50 projects: the Purpose. As already explained, this category identifies the final results of the project, intended as the category of the customer that the project will reach, the type of product that the project will offer and the territorial diffusion of the project.

The full analysis is available in *Appendix C*.

Client

The subcategory Client indicates the type of customer that a project will serve. It is immediately evident that most of the projects, to be exact 56% of the total, reach customers of

a *public* nature only. Since these projects, the SCPs, intended to increase the quality of life of citizens, it seems obvious to us that their client is mainly the community.

It should also be noted that only 6% of the total SCP is destined exclusively for *private* entities.

Consequently, the benefit of 38% of the remaining projects is achieved by a double clientele: both *public and private* clientele. A good part of the projects, therefore, affects directly and indirectly public and private entities: the citizen who uses Bike Sharing is certainly the direct customer, but also the company that supplies bicycles and protections receives benefits from this service.

We can therefore deduce how SCPs bring advantages, simplifications and facilitations in the daily routine of the whole population.

Product

As far as Smart Cities products are concerned, we can make a similar reasoning, but classifying products in *direct* and *indirect* is not correct.

Some projects have made clear from the outset the goal they want to achieve: an application that allows you to monitor public transport timetables in real time, the construction of cutting-edge buildings, the use of solar panels to power the parking meters. Others, however, do not have a well-defined goal, but they bring advantages on many fronts through, for example, a massive data collection that is obtained with an operational control centre.

We can therefore say that SCPs have *specific* and *non-specific* products: some projects know exactly how they will benefit users, others provide the necessary tools to make improvements in the quality of life of citizens.

As can be seen in Figure 32, these two types of products are roughly distributed equally. We note in fact how 52% of the projects are born with a *specific* product and how 48% instead have a *non-specific* product.

Despite this difference in definition, however, there is no doubt that each project has the purpose of bringing benefits to the whole community, regardless of how it does it.

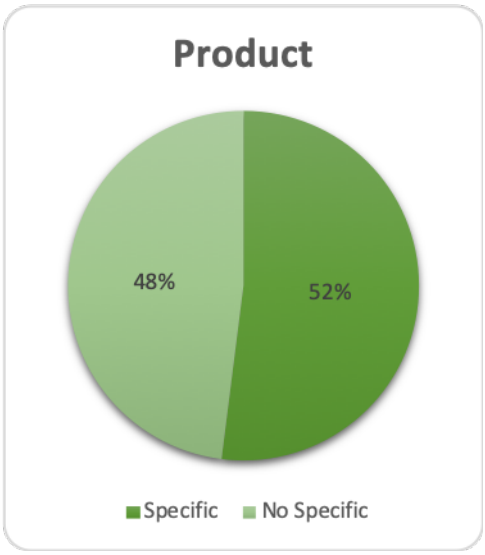


Figure 32 - Product

Geographical target

The last subcategory of taxonomy identifies the geographical target that a project covers, in fact a SCP can extend to urban, national or international level. As can be understood, this means that its benefits are destined for a single city, for a network of cities in a single state, or for multiple cities distributed throughout the world.

From the Figure 33, it emerges that, for the sample of projects that we have studied in our analysis, the diffusion of the single project occurs mainly at the *urban* level, with 86% of the total. In fact, the projects analysed are for the most part moderate projects that focus on the individual city, while managing to guarantee a very high level of monitoring and efficiency of the project itself.

The 12% of the projects, however, covered the entire *nation*, bringing benefits to various cities in the South American state.

Finally, only 2%, that it means one project, was a *worldwide* initiative. The project in question was carried out by Brazilian and Canadian companies and universities, and had the aim of becoming an international model, managing to raise awareness among people on the issue of sustainability and waste of energy.

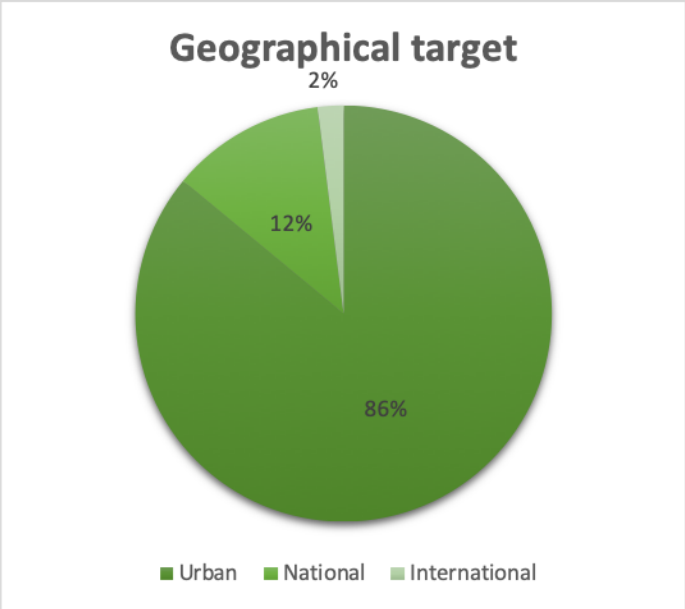


Figure 33 - Geographical target

Chapter 4
Tools

In Chapter 1, we gave an overview of the Smart City concept and the elements that make it up, observing how this concept has evolved over the years and what factors are taken into consideration in calculating the smartness of a city.

In Chapter 2, we created an overview of the Brazilian scenario, taking into consideration economic and social elements.

In Chapter 3, we deepened the analysis of the taxonomy of Perboli et al. (2014), applying it to 50 Brazilian projects so as to be able to extrapolate a trend of Smart Cities in the South American state.

Now, in Chapter 4, we will try to detect some recurring pattern with respect to the Objectives / Tools categories, based on the taxonomy's application results, and will go into detail on the project *Smart city concepts in Curitiba - Innovation for sustainable mobility and energy efficiency*, and in particular we will examine the technologies that have been implemented or integrated in the city to achieve the expected results.

4.1 Detected analogies

By taking advantage of the analysis that taxonomy provided us, we were able to find some recurring phenomena. It has emerged, in fact, that sometimes there is a more or less marked correspondence between the use of certain tools and the objective of the project. This means that certain tools are characteristic of certain areas, making them fundamental tools within the project, and this result helps us to identify recurring patterns that can be used for the implementation of future projects.

4.1.1 Cloud Computing -> Social Innovation

One of the trends highlighted by the analysis of the projects concerns the use of *Cloud Computing* in projects aimed at *Social Innovation*. In fact, from the application of the taxonomy, it emerged that Cloud Computing was used in 24 projects out of 50, of which 20 had Social Innovation as their target (83.33%).

ID	Project	Objectives	Tools
		Social Innovation	Cloud Computing
1	Innovation for sustainable mobility and energy efficer		1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
4	Digital Favelas	1	1
5	City Operations Centre	1	1
7	Urban Futurability	1	1
9	Integração eletrônica transporte público		1
12	ZUP	1	1
14	Internet Social	1	1
17	Central de monitoramento	1	1
22	CIGE	1	1
24	CCO	1	1
25	ICI	1	1
29	Transforma Recife	1	1
31	POADigital	1	1
34	Parque Tecnológico	1	1
35	Projeto Cidade Digital E Projeto Conecta	1	1
36	Centro de Cooperação da Cidade		1
38	Programa Municípios eficientes		1
39	Polo Digital	1	1
40	Soluções Ericsson Cidades Inteligentes	1	1
46	Extreme Networks Caixa do Sul	1	1
48	Sistema de videomonitoramento	1	1
49	CCO	1	1
50	Programa Inovação	1	1
	TOT.	20	24
		83,33%	

Table 1 - Cloud Computing -> Social Innovation

We can therefore deduce that there is a correspondence between Cloud Computing and Social Innovation; in fact, it is an area that manages an immense amount of data from multiple technologies, and which therefore requires a device capable of storing, processing and making this information accessible at any time and place.

4.1.2 Data Base -> Social Innovation

Another technology strongly characterizing the area of *Social Innovation* is the *Data Base*. In fact, the Data Base has been used in 32 projects out of 50, of 24 have been implemented in the Social Innovation sector (75%).

ID	Project	Objectives	Tools
		Social Innovation	Data Base
1	Innovation for sustainable mobility and energy effic		1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
4	Digital Favelas	1	1
5	City Operations Centre	1	1
6	Planet SC/InLoop	1	1
7	Urban Futurability	1	1
9	Integração eletrônica transporte público		1
12	ZUP	1	1
14	Internet Social	1	1
16	Educação tempo integral	1	1
17	Central de monitoramento	1	1
18	Parceria Samsung		1
20	Rio Smart City		1
22	CIGE	1	1
23	luminárias inteligentes		1
24	CCO	1	1
25	ICI	1	1
27	Playtown Recife	1	1
29	Transforma Recife	1	1
30	Cidade Cognitiva	1	1
31	POADigital	1	1
32	CittaMobi	1	1
34	Parque Tecnológico	1	1
35	Projeto Cidade Digital E Projeto Conecta	1	1
36	Centro de Cooperação da Cidade		1
38	Programa Municípios eficientes		1
39	Polo Digital	1	1
40	Soluções Ericsson Cidades Inteligentes	1	1
43	Monitoramento no parque da biodiversidade		1
48	Sistema de videomonitoramento	1	1
49	CCO	1	1
50	Programa Inovação	1	1
	TOT.	24	32
		75%	

Table 2 - Data Base -> Social Innovation

The reason why the Data Base is so important in Social Innovation projects is the same as Cloud Computing: this sector is called to manage a quantity of data that makes it necessary to use both digital (Cloud Computing) forms of storage solids (Data Base).

4.1.3 Decision Support System -> Energy

Another trend that emerged from the analysis is the use of *Decision Support Systems* in projects aimed at the *Energy* sector. Taxonomy shows us that DSS have been used in 8 projects, of which 6 related to the energy sector (75%).

ID	Project	Objectives	Tools
		Energy	Decision Suppo
1	Innovation for sustainable mobility and energy efficer	1	1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
7	Urban Futurability	1	1
13	Praça inteligente	1	1
15	Parquímetro Street	1	1
29	Transforma Recife		1
38	Programa Municípios eficientes		1
47	Laboratoório Digital	1	1
	TOT.	6	8
		75%	

Table 3 - Decision Support System -> Energy

It is quite understandable, in fact, that to optimize the energy system of a city there is the need to use increasingly complex calculation algorithms, and in this sense the Decision Support Systems give the necessary support to make the best decisions, for example, for reduce energy waste or monitor its use.

4.1.4 Innovative Sensors -> Security & Energy

The *Innovative Sensors* are mainly used in the *Security* and *Energy* sectors.

As regards Security, in fact, 13 of the 17 projects in which the Innovative Sensors were used concern the Security sector (76.47%).

ID	Project	Objectives	Tools
		Security	Innovative Sens
1	Innovation for sustainable mobility and energy efficer		1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
5	City Operations Centre	1	1
8	Programa de Eficiência Energética		1
9	Integração eletrônica transporte público	1	1
10	Operação Caça vazamentos		1
17	Central de monitoramento	1	1
22	CIGE	1	1
24	CCO	1	1
25	ICI	1	1
34	Parque Tecnológico	1	1
36	Centro de Cooperação da Cidade	1	1
40	Soluções Ericsson Cidades Inteligentes	1	1
42	Uso inteligente da água		1
43	Monitoramento no parque da biodiversidade	1	1
48	Sistema de videomonitoramento	1	1
49	CCO	1	1
	TOT.	13	17
		76,47%	

Table 4 - Innovative Sensors -> Security

It is quite evident how the Innovative Sensors are used in the Security sector: to give two examples, just think of the sensors that detect movements and send alarm signals, or all those sensors integrated in the Central de monitoring to guarantee the safety of citizens.

As for Energy, on the other hand, 12 of the 17 projects in which the Innovative Sensors were used are projects in the energy sector (70.59%).

ID	Project	Objectives	Tools
		Energy	Innovative Sens
1	Innovation for sustainable mobility and energy efficer	1	1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
5	City Operations Centre	1	1
8	Programa de Eficiência Energética	1	1
9	Integração eletrônica transporte público	1	1
10	Operação Caça vazamentos	1	1
17	Central de monitoramento	1	1
22	CIGE		1
24	CCO	1	1
25	ICI	1	1
34	Parque Tecnológico		1
36	Centro de Cooperação da Cidade		1
40	Soluções Ericsson Cidades Inteligentes	1	1
42	Uso inteligente da água		1
43	Monitoramento no parque da biodiversidade		1
48	Sistema de videomonitoramento	1	1
49	CCO	1	1
	TOT.	12	17
		70,59%	

Table 5 - Innovative Sensors -> Energy

As for Security, the Innovative Sensors are ideal for monitoring, receiving and sharing information on the energy system of a city. This information allows the optimization of the energy system and the identification of anomalies in the system, and thanks to the integration with the other tools adopted in the system, a significant improvement in the efficiency of the entire complex can be obtained.

4.1.5 Legal and Financial Tools -> Social Innovation

Again, for *Social Innovation*, another category of tools that matches the requirements of this sector is *Legal and Financial Tools*. In fact, these tools were used in 11 projects out of 50, 10 of which related to the Social Innovation area (90.91%).

ID	Project	Objectives	Tools
		Social Innovatic	Legal and finan
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
17	Central de monitoramento	1	1
24	CCO	1	1
29	Transforma Recife	1	1
31	POADigital	1	1
34	Parque Tecnológico	1	1
35	Projeto Cidade Digital E Projeto Conecta	1	1
43	Monitoramento no parque da biodiversidade		1
46	Extreme Networks Caixa do Sul	1	1
49	CCO	1	1
50	Programa Inovação	1	1
	TOT.	10	11
		90,91%	

Table 6 - Legal and Financial Tools -> Social Innovation

These technologies are necessary when, for example, legal, privacy, GDPR and asset management issues arise within projects.

4.1.6 Smart Grids -> Energy

Finally, the most recurring pattern, with 100% of the cases, refers to *Smart Grids* and *Energy*: this tool was used for 10 projects and all 10 had the energy sector as their goal.

ID	Project	Objectives	Tools
		Energy	Smart Grids
1	Innovation for sustainable mobility and energy efficer	1	1
2	Programa Nacional de Estratégias para Cidades Inteli	1	1
3	Wind Energy	1	1
6	Planet SC/InLoop	1	1
7	Urban Futurability	1	1
8	Programa de Eficiência Energética	1	1
9	Integração eletrônica transporte público	1	1
13	Praça inteligente	1	1
15	Parquímetro Street	1	1
40	Soluções Ericsson Cidades Inteligentes	1	1
	TOT.	10	10
		100%	

Table 7 - Smart Grids -> Energy

Smart Grids are a special tool for energy management; they allow you to manage and monitor the distribution of electricity from all sources of production and meet the different electricity needs of connected users, producers and consumers in a more efficient, rational and safe way. Therefore, their involvement in projects concerning the energy sector is logical.

4.2 The Project: *Innovation for sustainable mobility and energy efficiency (2014)*

The project was developed between October 2014 and December 2018 in the city of Curitiba by a group made up of Swedish and Brazilian actors both public and private. The main objective of the project was to explore innovative and sustainable solutions in the urban mobility sector, with a consequent increase in energy efficiency and reduction of gas emissions, through the insertion of public electric buses.

As a first step, two electric buses have been tested and its environmental impacts have been assessed, as well as the effects that a mass production and diffusion would have been assessed.

To achieve success, the project was developed using a systematic approach and included the participation of stakeholders such as politicians, experts and citizens.

One thing to highlight is how Curitiba, with its 1.74 million inhabitants, has always been a city that drives change, especially by planning sustainable developments. Over the years, Curitiba has implemented urban solutions that have shaped the city, including solutions for creating mass transportation using Bus Rapid Transit (BRT) systems. In this scenario, in order to achieve the desired end, the city must take further actions such as the introduction of new transport technologies, focusing, among others, on energy efficiency, safety, local and global environmental impacts, convenience and cost minimization.

Returning to the project, we can say that:

- The project addressed different aspects of electric mobility: the demonstration of 2 electric buses on existing routes in Curitiba; the analysis of the impacts of electric buses on energy, pollution and noise levels; the evaluation of the role of ICT infrastructures in this context. The results obtained provide advice to the planners of future interventions, as they demonstrate how all the aforementioned activities bring benefits to the entire community;
- The project favoured Curitiba's use of open data. Open data are the basis of the engagement of university students, because in this way they can be involved in the problems of the city and can make their contribution in solutions;
- The project has helped to form a strong alliance between consortium partners: KTH, UTFPR, the City of Curitiba, URBS, IPPUC, CISB, Saab, Volvo and Combitech are the main players;
- The project led to the creation of a Swedish-Brazilian transdisciplinary platform that allows to centralize different projects with a common purpose: urban sustainability.

4.2.1 The test phase

To demonstrate the usefulness of the project, initially two types of buses were inserted in two existing routes: a hybrid-electric and a plug-in hybrid-electric bus. This demonstration allowed to collect quantitative data such as the increase in energy efficiency, the reduction of greenhouse gas emissions and silent driving, which provided suggestions at an operational level. Insights were provided in relation to the challenges implied in up-scaling bus electrification.

Below, in Figure 34, we can see the buses used in the test phase, with the details of the routes in which they circulated.

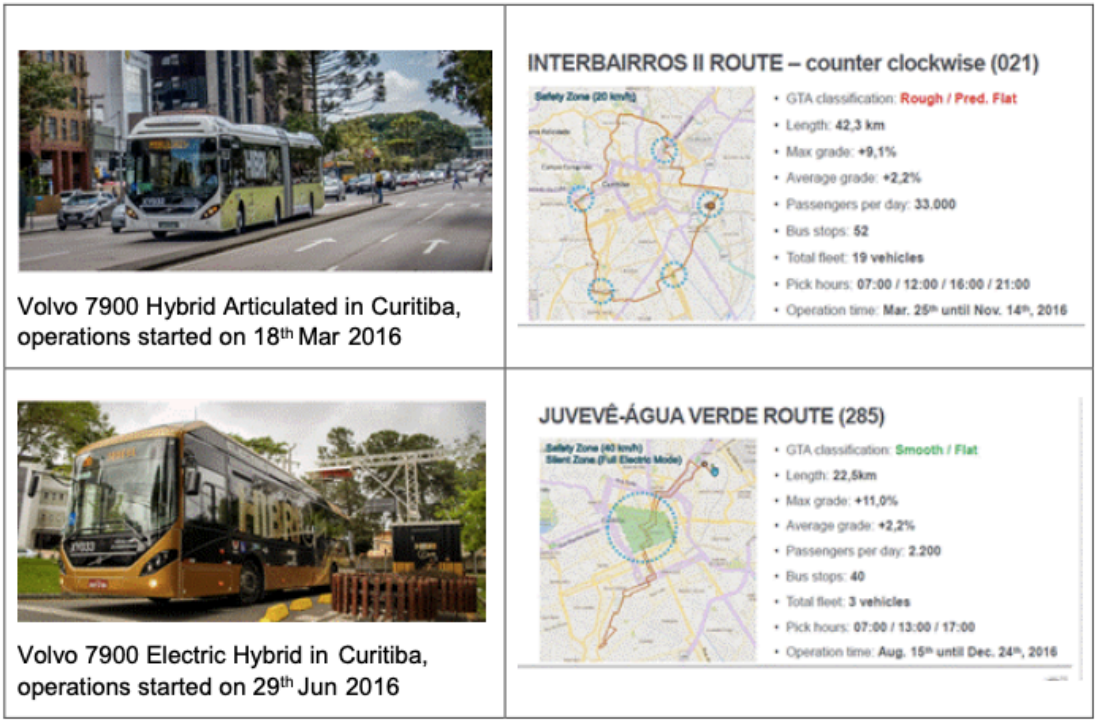


Figure 34 - Electric buses and routes in Curitiba

The Volvo 7900 Articulated Hybrid can carry up to 154 passengers and circulated on the Interbarrios II route. The Volvo 7900 Electric Hybrid can carry up to 91 passengers and circulated on the Juvevê-Agua Verde route (route 285).

The analysis was then extended to all types of buses that generally traffic the streets of Curitiba. In particular, it turned out that with a hybrid-electric two-axle city bus there is a 30% reduction in fossil energy per kilometre, and with a plug-in hybrid-electric two-axle city bus there is a 75% reduction compared to a conventional bus of the same size.

However, aspects that must be considered because they can influence the general objectives are the behaviour of bus drivers, the load of passengers and the price of refuelling.

Returning to the installation of electric buses in the city of Curitiba, a large volume distribution of these means of transport still requires a lot of attention to maximize benefits and reduce costs. In fact, an analysis of the scenario for the spread of electric buses reported 26 possible routes in which to implement these technologies, which would lead to a 12% reduction in energy consumption and 74% in CO2 emissions, but at the same time it would lead to a 9% increase in total costs compared to the current bus configuration (*source: Innovation for sustainable mobility and energy efficiency - Executive Summary, 2018*).

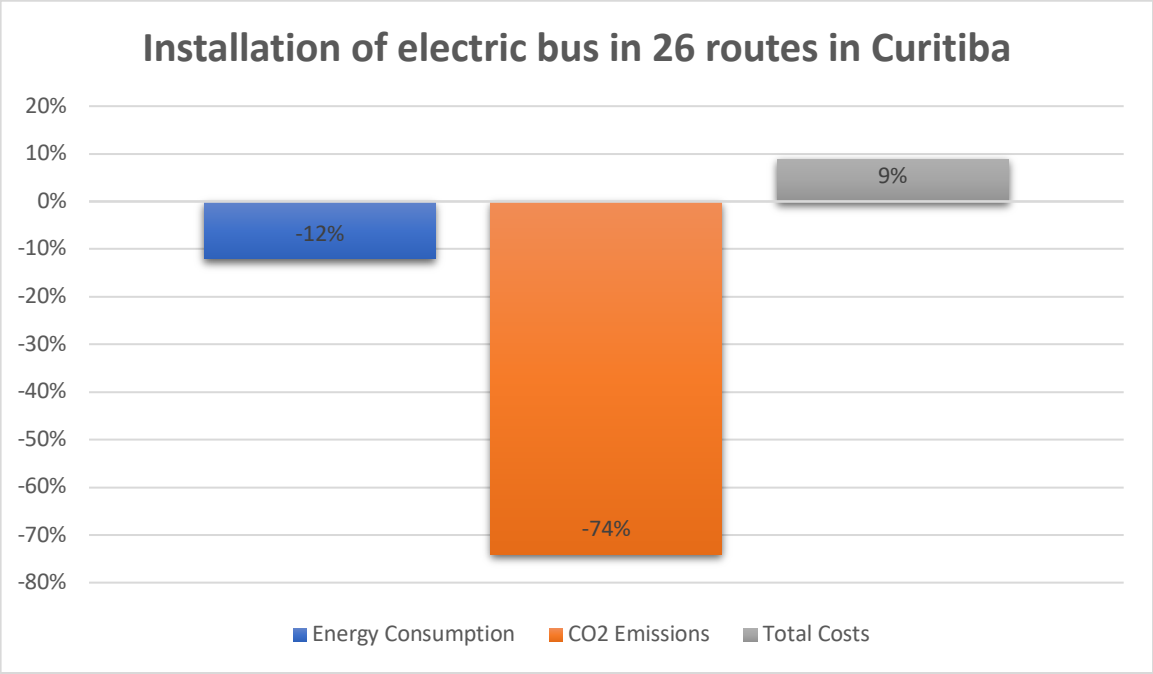


Figure 35 - Test phase results (*source: Innovation for sustainable mobility and energy efficiency - Executive Summary, 2018*)

The increase in costs is due to the high cost of electricity in Brazil, which alone the high efficiency of the service offered cannot compensate.

It is therefore clear that an integrated approach is needed to allow this innovation to bring benefits in all respects. The integrated approach is also necessary for the installation of infrastructures, such as charging stations, to reduce those costs that can be an obstacle to date.

Another service offered by the new buses tested in Curitiba included the offer of Wi-Fi connection on board. The quality of service perceived by users does not only depend on the Wi-Fi access point of the buses, but also on the mobile broadband that connects the buses to the operators, user devices and other connection points. Therefore, efficient wireless

broadband with high capacity must be provided in buses in order to offer a high-quality service that can improve the experience of passengers on board.

4.2.2 The effects of the Project

To summarize, therefore, we can identify the key objectives of the project in the following points:

- Demonstration of new technology for mass transport corridors;
- Planning of plug-in hybrid-electric bus operation;
- Providing high-capacity wireless broadband along Curitiba transportation corridors;
- Energy and climate scenarios with improved environment and mobility;
- ICT infrastructure for Open Data integration and interactive information sharing;
- Planning of electro-mobility in Curitiba.

These objectives were pursued by analysing functional, cost-efficient and environmental-friendly concepts.

The result of the analysis described above showed that despite the integration of electric buses it leads to an improvement of sustainability at local and global level, to exploit the full potential of this service it is necessary to forge strong collaborations between multiple stakeholders.

For this reason, a platform has been developed within the project in which different stakeholders can share data and information, and this collaboration highlights how innovative concepts can become reality through the trust that is created between the various actors involved.

To guarantee the total effectiveness of the process, a good and common understanding of urban problems, collaboration in the planning and planning of participatory actions were necessary.

Given the success of the results obtained, the project immediately became an international reference and paved the way for future collaborations between Swedish and Brazilian stakeholders for projects in the city of Curitiba and other cities in the South American state.

New challenges await us to continue building a cooperative model of this type and implement new concepts for sustainable mobility. The commitment to sustainable development is a global commitment, but the compromises between immediate needs and long-term goals will have to be addressed effectively in cities. Only in this way can a commitment to sustainability become a clear path to humanity's future.

4.3 The adopted technologies

More than half of the world's population lives in cities, and the population is expected to grow by an additional 2.5 billion people by 2050. The cities will therefore face an increase in environmental pressures and the need for new infrastructures, with a consequent request for a better quality of life at a sustainable cost.

Smart technologies can help meet these challenges by driving the new wave of public investment. Everything starts from the data: cities generate an immense amount of data, from these data municipal governments can come up with solutions to respond to fluid situations, allocate resources wisely and plan for the future.

Furthermore, equipping individuals and companies with real-time information allows you to make better decisions and play an active role in the general definition of the city's performance.

Returning to our case, the size and complexity of this project is also inherent in the technologies developed and used in its realization. In fact, there are really many tools used in this project to allow the new initiative to offer an improvement compared to the conventional service.

In the following paragraphs we will go into detail on the individual technologies adopted, trying to understand how they offer a competitive advantage and how these have been integrated into the existing urban reality.

4.3.1 Cloud Computing

Developed a decade ago, cloud computing is the technology that allows you to take advantage, via remote server, of software and hardware resources, the use of which is offered as a service by a provider. In essence, therefore, cloud computing is the offer of computing services via the Internet.

Cloud computing is revolutionizing many corporate behaviours, because through it, new services and applications can be created, a large amount of data can be stored and a backup for information restoration can be used to host sites web and streaming services, and can also be used to analyse data and derive strategic models and production plans.

The benefits of this service are manifold, which is why more and more SMEs are acquiring cloud computing solutions. Lower management costs, increased productivity and security are just some of the benefits that the cloud brings.

By analysing more technical details, the architecture of a cloud system can be divided into two macro parts: the front-end and the back-end. The front-end is what the user sees and interacts with, is run on the customer's computer and consists of the application needed to

access the cloud, while the back-end is the core of the system, where all the resources and computing units that are used to operate the system lie.

Looking in Figure 36, the cloud software infrastructure layer provides the basic resources that are offered as services to the overlying layers: computational resources (usually virtual machine environments), memory and communication on the network. These services can be used individually, as typically happens with storage services, but are often offered in a *bundle*. These services offered together are often referred to as Infrastructure as a Service (IaaS).

The cloud software environment layer provides services at the application platform level:

- a development and execution environment for services and applications written in one of the supported languages;
- memory devices;
- communication infrastructure.

This layer corresponds to the Platform as a Service (PaaS). The above applications, marked as Cloud applications in Figure 36, represent the Software as a Service (SaaS) and are the applications (generally implemented as Web Service) accessible to cloud customers.

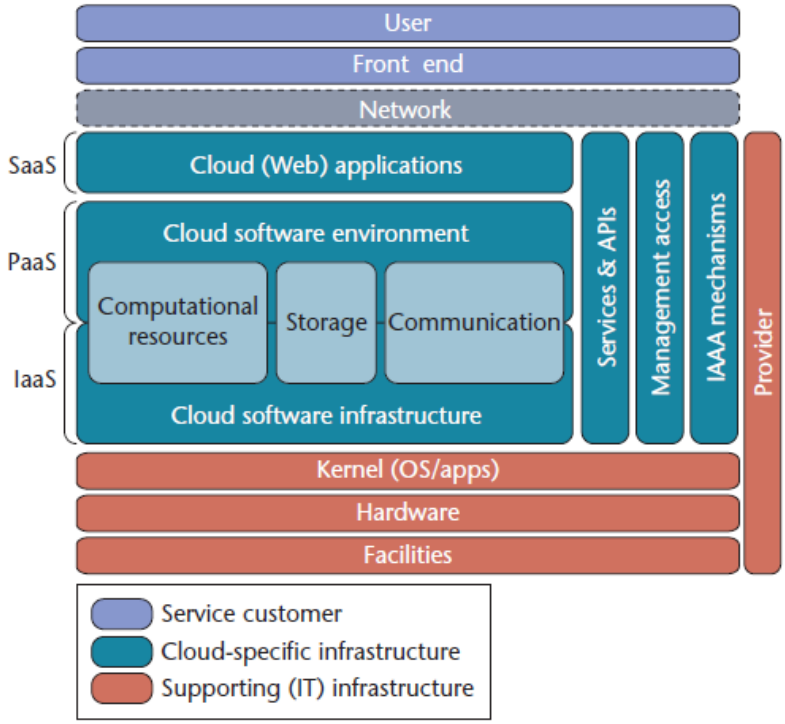


Figure 36 - Cloud Computing architecture

One of the technologies on which cloud computing is based is virtualization. A virtual machine is the logical container of a guest operating system and the applications it runs. It is

stored as a disk image and therefore can be transferred from one server to another. The hypervisor is what manages the virtual machines running on the same physical server, and presents the guest operating systems with virtualized views of the physical hardware and resources. He also deals with the set-up, shutdown and migration of the virtual machines for which he is responsible.

Therefore, the cloud computing models offered to companies are basically three:

- Iaas (Infrastructure as a Service) - The most popular, consists of virtualized hardware that includes virtual server space, network connections, bandwidth, IP addresses and load balancers. Physically, the hardware resource group is extracted from a multitude of servers usually deployed to numerous data centres, whose maintenance is the responsibility of the cloud provider. Instead, the customer has access to virtualized components to build their IT platforms.
- Paas (Platform as a Service) - Provides developers with a platform for building applications and services on the Internet; the services are hosted in the cloud and users can easily access them through their browser.
- Saas (Software as a Service) - cloud service with which consumers can access software applications via the Internet. Practically. it is a rental service rather than a subscription.

The implementation

Taking into consideration our specific case, Cloud Computing has been used by City Collaboration Centers to manage a huge amount of data. The City Collaboration Center (CCC) is a control centre that allows the connection between different sectors of society, and creates an information platform to support advanced decisions, efficient dialogues and the best use of resources.

In fact, the City Collaboration Center receives millions of information every day that is transmitted through Optical Networks, and is stored and processed through Cloud Computing, considered the best solution for these activities.

This tool was provided by the KTH Royal Institute of Technology in Stockholm, in a joint venture with SAAB, and was used, for example, to collect real-time traffic data on a cloud service platform hosted by Microsoft Azure.

In addition, the Universidade Tecnológica Federal de Paraná UTFPR has implemented a new algorithm for the re-establishment of cloud services in optical networks with the aim of reducing the network blocking probability.

4.3.2 Data Base

A database is a set of structured information (or data) typically stored electronically in a computer system. Usually, the database is controlled by a DBMS (Database Management System). The data within the most common types of databases currently in operation are generally presented in rows and columns contained in a series of tables to ensure the efficiency of data processing and querying. These data can then be easily viewed, managed, modified, updated, checked and organized.

The evolutionary growth of databases has been remarkable since its inception in the early 1960s. The original systems used to store and manipulate the data were the databases dedicated to navigation, such as the hierarchical database (which was based on a tree model and allowed only a one-to-many relationship) and the network database (a more flexible model capable of allowing multiple relationships). Although simple, these early systems lacked flexibility. In the 1980s, relational databases gained notoriety, followed by object-oriented databases in the 1990s. More recently, NoSQL databases have appeared in response to the growth of the Internet and to meet the need for greater speed and processing of unstructured data. Today, databases in the cloud and databases with Self-Driving features are opening the door to innovation regarding data collection, storage, management and use procedures.

There are many different types of databases and the most suitable for a specific organization depends on how that organization intends to use the data:

- Relational databases;
- Object-oriented databases;
- Distributed databases;
- Data warehouse;
- NoSQL database;
- Graphical databases;
- OLTP database.

In addition to these, believed to be the classic models, changes in approach to technological development and extraordinary progress, such as the cloud and automation, are pushing the databases in completely new directions. Here are some of the most recent databases:

- Open source database: an open source database system contains open source source code;
- Cloud database: a cloud database is a set of data, structured or unstructured, that resides in a private, public or hybrid cloud computing platform;
- Multi-model database: multi-model databases associate different types of database models in a single integrated backend;

- Document database / JSON: document databases, designed to store, retrieve and manage document-oriented information, represent a modern tool for storing data in JSON format and not in rows and columns;
- Database with Self-Driving functionality: the most innovative and revolutionary types of databases, namely databases with Self-Driving features, are cloud based and use Machine Learning features to automate tuning, security, backup, updating and other routine management activities traditionally performed by Databases. Administrator.

The implementation

In *Smart city concepts in Curitiba - innovation for sustainable mobility and energy efficiency*, the databases were used to contain the information coming from the City Collaboration Center and to make it available to local universities, ordinary citizens and other organizations to allow R&D activities. It permitted to implement new applications with the aim of improving the quality of life of the citizens of Curitiba.

In fact, within the project, the databases have been used both by the City Collaboration Center and by other structures (for example, universities, private companies and citizens), all with read and write access. All the figures involved could, therefore, access the information contained in the databases and could also feed them.

In addition, the structures involved in the project had the opportunity to access databases from third-party organizations to retrieve further information. For example, by accessing the open database, it was possible to obtain data on building permits, population densities, social housing locations and cost of land.

4.3.3 Decision Support System

A Decision Support System (DSS) is a decision support software system, which allows to increase the effectiveness of the analysis as it provides support to all those who must make strategic decisions in the face of problems that cannot be solved with models of operational research. The main function of a DSS is to quickly and flexibly extract information useful for decision-making processes, coming from a significant amount of data.

The DSS relies on data in a database or a knowledge base, which help the user to decide in an optimal or sub-optimal way; it is not only a computer application, because it also contains Business Intelligence and Expert Systems technologies, such as decision support models.

The essential aspects of a DSS can be enclosed in:

- ease of use within the reach of all users;
- interactive environment;

- possibility for the system to provide support to the decision-making process;
- effectiveness in the use of models and in data analysis.

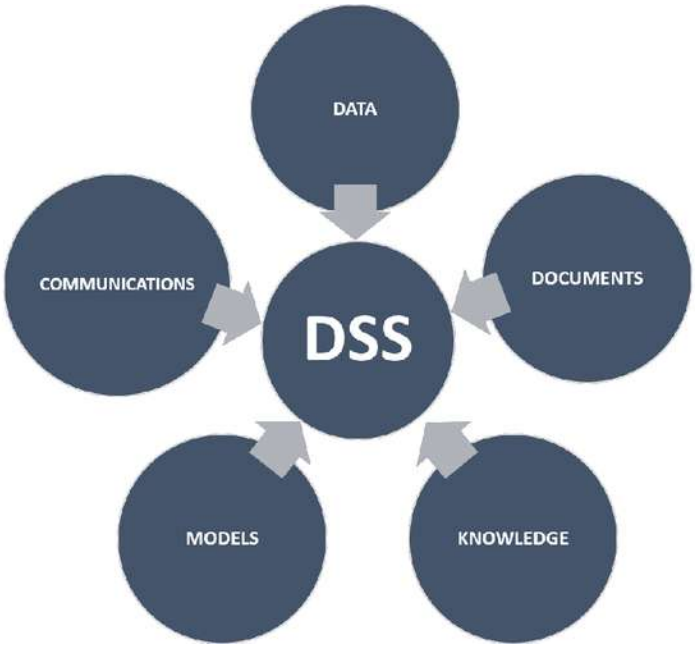


Figure 37 - Decision Support System

Usually a DSS consists of the following main components:

- Database. The database collects information and data that interest the user. These data are independent of management data and are often integrated with external information.
- Base of models. A model base contains the procedures necessary to solve user problems, its function is therefore to organize the management of all models to consolidate the data processing process, in order to rationalize the internal decision-making process.
- Software system. The software system is divided into three components:
    - DBMS (Database Management System), is a software that allows you to schematically define the organization of the data, store it, modify it, manage it allowing a simple extraction of the database;
    - MBMS (Model Based Management System), facilitates the storage, modification and use of models;
    - DGMS (Dialogue Generation and Management System), is the software that designs the user interface, therefore it has the task of making the operation that the user performs on the DSS more accessible.

- Data Mining. Data mining is an operation that identifies and extracts information, such as relationships, associations between the data in the database previously unknown to the user.
- Query. Queries query the database using specific instructions for the product being used, speed up the processing of information and simply provide elements to confirm or deny the hypotheses made by the user.
- OLAP. OLAP acronym for On Line Analytical Processing is a technique that analyse in depth a large amount of data, it only provides elements to confirm or deny the hypotheses formulated by decision makers.
- Knowledge. Knowledge, also knowledge management, is used to organize data and information in such a way as to provide knowledge, experience, continuous learning, and helps to know well the organization of data and the type of research.

The implementation

In the City Collaboration Center described in the previous paragraphs, an advanced decision support platform has been implemented, which, having received certain categories of information as input, is able to provide support for strategic decision-making activities.

Given their functioning, therefore, it is logical that Decision Support Systems are used by operators working in the CCC. In particular, they are a support tool for those figures who deal with making strategic decisions, because, through algorithms, they transform the data they receive into strategic advice.

26 practical routes have been identified by receiving a practical example of the project examined, through the input of data regarding traffic in the city of Curitiba, the average fuel consumption of cars, CO2 emissions at peak times and others. to implement the electric bus service. With a view to energy optimization, the electrification of 12 of these 26 routes would lead to a 12% reduction in energy consumption and 74% of CO2 emissions, despite a modest 9% increase in total costs caused by higher cost of vehicles.

4.3.4 Information and Communication Technologies

The Information and Communications Technologies (ICT) are the set of methods and techniques used in the transmission, reception and processing of data and information (including digital technologies).

The use of technology in the management and treatment of information has assumed growing strategic importance for organizations and citizens as a result of the internet boom that occurred in the 1990s. Today computer science (digital devices and software programs)

and telecommunications (telematic networks) are the two pillars on which the information society is based.

ICT includes all those professional areas that concern the design and technical development of digital communication.

ICT are used in many areas of daily life: being used in a large variety of public and private areas without being dedicated to a specific use, ICT technologies can be considered general purpose technology and are increasingly connected to social and economic development of human communities.

ICTs include the resources necessary to manipulate information, in particular computers, software, networks, and web sites and platforms necessary to convert, store, manage, transmit and find it.

These technologies can be grouped based on:

- The networks. The concept of telecommunications network refers to the so-called *information highways*: the information highway or transport network is a wired (copper or fibre optic) or non-wired network (radio bridges and satellites) that combines traditionally offered services from different suppliers: from the telephone to the television to the digital contents, obviously including the traditional IT services.
- The terminals. They act as an access point for citizens to the information society. Furthermore, they are one of the elements that have evolved more over time: the appearance of terminals that allow you to take advantage of the digitization of information and the growing availability of infrastructures for the exchange of digital data is continuing. Various technological innovations have contributed to all this, which have coincided over time to favour a favourable environment. In fact, today the presence of a personal computer in homes is a common fact.
- ICT services. The first ICT services were e-mail and search engines, followed by a second group of ICT services, including e-commerce, online banking, access to information and entertainment content and access to public administration services. But the main change that the technological possibilities have caused has been the emergence of formulas for cooperation between network users, breaking the classic one-to-one supplier-customer paradigm. The emergence of virtual communities has favoured the emergence of a series of products and forms of networking which, collectively, have been collected under the concept of Web 2.0, such as peer-to-peer services.

The implementation

For this project, several Swedish and Brazilian ICT companies have been involved with the request to provide ICT technologies with the aim of achieving sustainable urban development in Curitiba.

A complex ICT ecosystem is needed to provide the necessary support for collecting and managing the collected data and trigger the actions controlling certain functions in the Smart City environment. A huge amount of data from different sources has to be processed safely to generate usable information for various stakeholders. In this context, the ICT infrastructure becomes the basement of a CCC operation, supporting its processes.

Given the importance described above, ICTs are the most used tool within the project. In fact, it is a tool that is used, even unconsciously, by all the actors involved: bus drivers, operators within the CCC, researchers and many others, all have used ICT to achieve the aim of the project.

The ICTs have also been used to manage the communication between the intelligent sensors and the driver, as regards the Pedestrian & Cyclist Detection System, which consists in signalling in case of pedestrians or cyclists near the bus.

Furthermore, the work of the KTH-ONLab in Curitiba has focused on investigating various deployment options for the ICT infrastructure in the city. The objective is to understand the costs of providing broadband connectivity services over a given deployment area.

4.3.5 Innovative Sensors

The concept of smart sensors was first introduced by NASA in the spaceship development process, which led to the creation of the first prototype in 1979.

The intelligent sensor is a type of sensor that can detect information from a given object and can learn, judge and process signals, and also has communication and management functions. The intelligent sensor has the ability to automatically calibrate, compensate and collect data, demonstrating that it has high precision and resolution, high stability and reliability and good adaptability. In the 1980s, the intelligent sensor focused primarily on the microprocessor and integrated the sensor signal conditioning circuit, the microelectronic computer memory and the interface circuit into a chip, so that the sensor had some artificial intelligence. In the 1990s, intelligent measurement technology was further improved, so that the sensor to achieve miniaturization, integration, array, digital structure, convenient use, simple operation, and has the function of self-diagnosis, memory and information processing function, data storage function, multi parameter measurement, network communication function, logical thinking and judging function.

There are three types of smart sensors:

- Sensor with the ability to judge;
- Sensor with learning ability;
- Sensor with creative ability.

The intelligent sensor system is mainly composed of sensors, microprocessors and related circuits. The sensor converts the measured physical quantity and the chemical quantity into the corresponding electrical signal, sends it to the signal modulation circuit and then sends it to the microprocessor after filtering, amplification and A / D conversion. The microprocessor calculation, storage, data analysis and processing of the received signal, a sensor feedback circuit and the signal conditioning circuit are regulated in order to obtain regulation and control of the measurement process; on the other hand, the result of processing is transmitted to the output interface, the interface circuit after processing according to the output format, customization of the output interface of the digital measurement results. The microprocessor is the core of the intelligent sensor. Thanks to the functions of the various software, the sensor is simplified and the sensor performance is significantly improved.

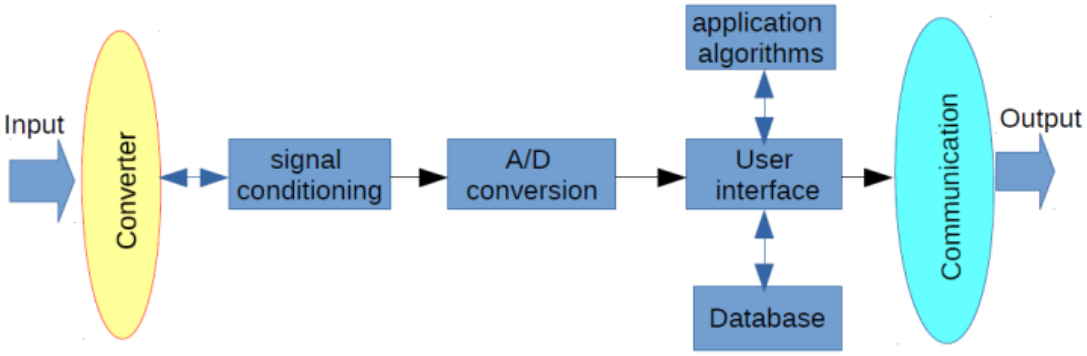


Figure 38 - Innovative sensor architecture

The implementation

In the city of Curitiba, Smart Sensors have been used to detect, process and send data on traffic, weather and pollution. In fact, by recording data on the conditions of the city through innovative sensors, the CCC prepares the necessary interventions to improve the quality of life of citizens.

The sensors were directly connected to the new technologies introduced by Volvo (Volvo 7900 Articulated Hybrid and Volvo 7900 Electric Hybrid), and this added value to the demonstration carried out, as it improved the traffic management capabilities inherent in the Saab SAFE system.

In addition to traffic flows, information relating to energy consumption and environmental impacts was monitored and communicated to city managers and users.

As mentioned above, intelligent sensors are one of the main components of the Pedestrian & Cyclist Detection System, with which the new Volvo 7900 Articulated Hybrid and Volvo 7900 Electric Hybrid can be equipped; this system, in fact, allows to detect pedestrians and cyclists near the bus, and send a signal to the driver to warn him.

The information obtained from intelligent sensors was exploited by various actors: the bus drivers, through their normal work, provided the intelligent sensors with data which would then be processed and sent; CCC operators used information on traffic, energy, pollution and more to feed the strategic decision algorithms; researchers to increase the level of detail of their studies through the information obtained from the sensors; citizens, indirectly, through their normal routine, sent the input data to the sensors.

4.3.6 Smart Grids

Smart Grids are intelligent grids, or rather a set of electricity grids and technologies that, thanks to the mutual exchange of information, allow you to manage and monitor the distribution of electricity from all sources of production and meet the different electricity requirements of connected users, producers and consumers in a more efficient, rational and safe way.

The smart grids will help the development of renewables since thanks to their contribution and presence a greater share of the production from renewables can be accommodated, ensuring reliable network management.

Furthermore, they constitute a necessity determined by the development of energy production on a peripheral basis of the network. The production of electricity, especially from photovoltaic systems, by small local producers is already a reality with important development and the network requires a necessary update, contemplating the need to manage situations in which peripheral production is limited or excessive compared to consumption.

Figure 39 - Smart Grids integrated in residential photovoltaic systems

The adoption of Smart Grids allows several benefits:

- They ensure the integration of distributed generation and guarantee the energy necessary for new electrical end uses, such as heat pumps, for example.
- They contribute to reducing the power outage times, allowing to improve the continuity of the service. All this thanks to technology: Smart Grids are equipped with automatic and optimal network reconfiguration functions and protections that quickly adapt to the type of network.
- They also allow to improve the security of the system through a more effective and punctual management of resources connected to the network, allowing an increase in the quantity of distributed generation connected to the network without compromising the quality of the supply.
- They allow to offer a faster response to unforeseen events and to carry out highly advanced, rapid and automated troubleshooting searches, minimizing downtime.

The best knowledge of the network, possible thanks to Smart Grids, allows you to develop it even more attentively to the needs of users.

Thanks to its ability to detect overloads, electricity is redirected in order to prevent or minimize a potential interruption and to work autonomously when conditions require rapid and safe resolution.

Then there is the importance given to the consumer, increasingly active, as a prosumer, which is an increasingly evident aspect.

Finally, Smart Grids are able to encourage the emergence of new market players, in order to offer network operators new services.

The implementation

Smart Grids, together with Information and Communication Technologies (ICT), are among the technologies most used by the Swedish - Brazilian consortium to develop electro-mobility, and energy efficient and low-carbon transport services in the city of Curitiba aiming at sustainable urban development

Within the project, urban evolution has been rethought in the face of technological developments such as Smart Grids and electromobility; environmental requirements such as reduced footprint and greenhouse gas emissions, and social needs such as urban safety, comfort and quality of life are some of the aspects that have been reviewed.

Similarly, the management of Smart Grids will allow a better supply of information for a better integration of the urban functions of the city of Curitiba. The demarcated areas can be transformed into learning laboratories for the demonstration of urban technologies and solutions.

Analysing practical cases of the project, some of the activities in which Smart Grids were adopted are energy storage, load shedding, load balance and load transfer.

Smart Grids are included in the main section of the bus recharging stations, also present in the terminal but also at the bus stops. In fact, it is possible to load the bus quickly even during the passengers getting on and off.

Conclusions

In support of the analysis carried out, we report in this chapter the main evidence that emerged.

Brazil, with its 8.5 million km2 and 210,147,125 inhabitants, is part of a geo-economic aggregate, identified with the acronym BRICS (Brazil, Russia, India, China and South Africa), characterized by an economic condition in development, a large population, a vast territory, abundant strategic natural resources and a strong growth in GDP and share in world trade. Consequently, Brazil is paying more and more attention to the needs of its citizens, trying to satisfy them through the development of projects whose aim is to improve the quality of life of the whole community.

In this sense, the application of the taxonomy to the sample of 50 projects has highlighted the presence of a trend towards Social Innovation, to be understood as the offer of all those services whose purpose is to satisfy directly the primary needs of the community: to clarify, for example, *o Istituto Brasileiro de Geografia e Estatística (IBGE)* has made known the alarming fact that more than 7% of the Brazilian population is illiterate, followed by unemployment above 13 %, mainly distributed among the poorest population.

What the taxonomy has brought to light, in fact, is that 68% of 50 projects have had social impacts, bringing solutions to primary needs of different nature: a bus on which computers have been installed to allow anyone to access to the Internet (*Estação Digital Móvel* in João Pessoa), the creation of monitoring centres connected to video cameras scattered throughout the city to guarantee greater security for the inhabitants (*Central de monitoring* in Maringá) and the free offer of courses on digitization , IoT and other technological themes that have allowed many inhabitants to acquire useful skills in finding a job (*Maior sala de aula do mundo* in Sorobaga) are just some of the practical examples.

Another evidence that taxonomy has brought to light is the importance of Information and Communication Technologies (ICT) in the development of Smart City Projects. In fact, these technologies have been used in 100% of the projects, and this is explained by the fact that ICTs are considered one of the main pillars of the technological evolution that we are experiencing, therefore necessary for the creation of the cities of the future.

As for the promoters, managers and funders of the projects, studying the sample, it emerged that the aforementioned roles are mainly occupied by figures of a public nature, and

this matches with what was said above, being the first ones interested in meeting the needs of the own community.

My analysis then focused on the tools described and used in the sample of 50 projects and, taking advantage of the results obtained from the application of taxonomy, I was able to identify some recurring patterns between Tools and Objectives. In fact, there are more or less marked correspondences between these two categories; it emerged that some tools are particularly characteristic for some specific categories of projects, which I report below:

- Cloud Computing -> Social Innovation (83.33%);
- Data Base -> Social Innovation (75%);
- Decision Support System -> Energy (75%);
- Innovative Sensors -> Security & Energy (76.47% & 70.59%);
- Legal and Financial Tools -> Social Innovation (90.91%);
- Smart Grids -> Energy (100%).

The identification of this pattern can be of use for the implementation of future projects.

Finally, the Tools used in one of the 50 projects of the sample, *Innovation for sustainable mobility and energy efficiency (2014)* have been analysed in detail. In particular, I went into detail about their characteristics and identified the methodologies in which they were integrated into the project, what they are used for and by whom they have been used.

To conclude, Brazil has all the characteristics necessary to become a country on par with the most advanced states in the rest of the world. There is also a significant commitment from foreign companies (Samsung, Cisco, Volvo, etc.), which are contributing significantly to the economic development of this country, through the offer of their knowledge and technologies. If this trend persists also in the future, with the correct management and commitment by the whole community, Brazil will be able to reach considerable levels in the global economic landscape.

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Appendices

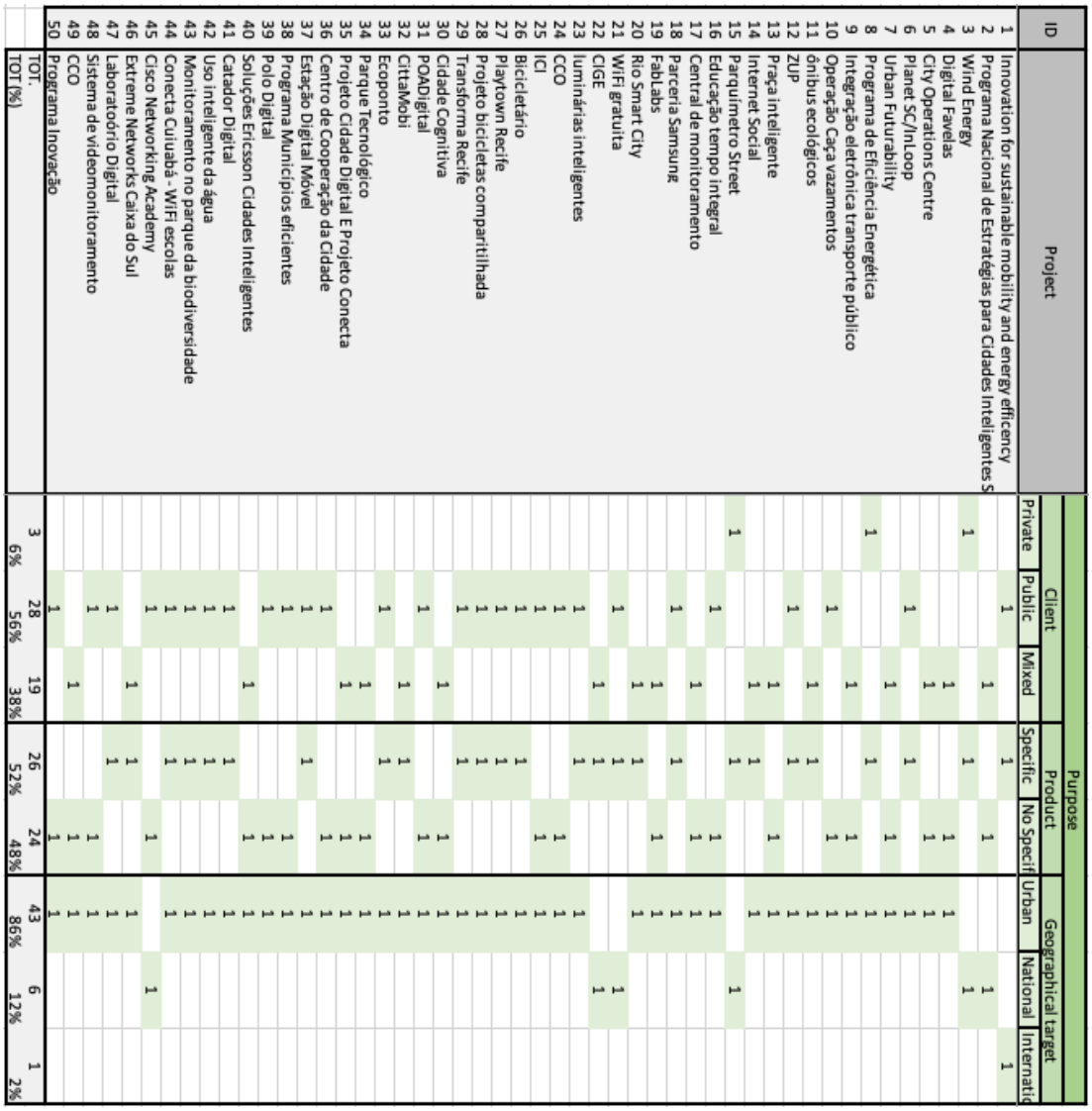
Appendix A - *Taxonomy, Description*

ID	Project	Description																								
		Objectives								Tools									Project initiator			Stakeholders				
		Wate	E-Gov	Build	CO2 E	Energ	Secur	Socia	Trans	Cloud	Data I	Decis	Inforn	Innov	Legal	Other	Porta	Smart	Privat	Publi	Mixed	City	Consu	Admi	SMEs	Unive
1	Innovation for sustainable mobility and energy efficency				1	1			1	1	1	1	1	1				1			1	1	1	1	1	1
2	Programa Nacional de Estratégias para Cidades Inteligentes S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1
3	Wind Energy				1	1							1			1		1		1		1	1	1	1	1
4	Digital Favelas		1	1	1		1	1	1	1	1		1			1	1				1	1	1	1	1	
5	City Operations Centre		1	1	1	1	1	1	1	1	1		1	1		1				1		1	1	1	1	
6	Planet SC/InLoop	1		1		1		1			1		1				1	1	1			1	1		1	
7	Urban Futurability					1		1		1	1	1	1			1		1	1			1	1	1	1	
8	Programa de Eficiência Energética	1		1	1	1							1	1		1		1	1			1	1		1	
9	Integração eletrônica transporte público				1	1	1		1	1	1		1	1		1	1	1		1		1	1	1		
10	Operação Caça vazamentos	1		1		1							1	1		1				1		1	1	1		1
11	ônibus ecológicos				1			1	1				1			1				1		1	1	1	1	
12	ZUP		1					1		1	1		1			1	1			1		1	1	1	1	
13	Praça inteligente					1	1					1	1			1	1	1		1		1	1	1		
14	Internet Social							1		1	1		1			1				1		1	1	1		
15	Parquímetro Street				1	1			1			1	1					1			1	1	1	1	1	
16	Educação tempo integral			1				1			1		1			1				1		1	1	1		1
17	Central de monitoramento		1	1	1	1	1	1	1	1	1		1	1	1	1	1			1		1	1	1	1	
18	Parceria Samsung				1				1		1		1			1	1				1	1	1	1	1	
19	FabLabs							1					1			1				1		1	1	1	1	
20	Rio Smart City				1				1		1		1			1	1			1		1	1	1	1	
21	WiFi gratuita		1					1					1			1	1			1		1	1	1	1	
22	CIGE			1			1	1		1	1		1	1		1				1		1	1	1	1	
23	luminárias inteligentes			1		1					1		1			1				1		1	1	1	1	
24	CCO		1	1	1	1	1	1	1	1	1		1	1	1	1				1		1	1	1	1	
25	ICI		1	1	1	1	1	1	1	1	1		1	1		1	1			1		1	1	1	1	
26	Bicicletário				1				1				1			1	1			1		1	1	1	1	
27	Playtown Recife							1			1		1			1				1		1	1	1	1	
28	Projeto bicicletas comparitilhada				1				1				1			1	1			1		1	1	1	1	
29	Transforma Recife		1					1		1	1	1	1		1	1				1		1	1	1	1	
30	Cidade Cognitiva		1					1			1		1			1					1	1	1	1	1	
31	POADigital							1		1	1		1		1	1					1	1	1	1	1	
32	CittaMobi		1		1		1	1	1		1		1				1			1		1	1	1	1	
33	Ecoponto			1				1					1			1				1		1	1	1		
34	Parque Tecnológico						1	1		1	1		1	1	1	1				1		1	1	1	1	1
35	Projeto Cidade Digital E Projeto Conecta						1	1		1	1		1		1		1			1		1	1	1	1	
36	Centro de Cooperação da Cidade		1		1		1		1	1	1		1	1			1			1		1	1	1	1	
37	Estação Digital Móvel							1					1			1	1			1		1	1	1		
38	Programa Municípios eficientes		1							1	1	1	1			1				1		1	1	1		
39	Polo Digital			1				1		1	1		1			1	1				1	1	1	1	1	
40	Soluções Ericsson Cidades Inteligentes	1	1		1	1	1	1		1	1		1	1		1		1			1	1	1	1	1	1
41	Catador Digital					1		1					1			1					1	1	1	1	1	
42	Uso inteligente da água	1						1					1	1		1				1		1	1	1		
43	Monitoramento no parque da biodiversidade		1				1				1		1	1	1						1	1	1	1	1	
44	Conecta Cuiuabá - WiFi escolas							1					1			1	1				1	1	1	1	1	
45	Cisco Networking Academy							1					1			1					1	1	1		1	
46	Extreme Networks Caixa do Sul					1	1	1		1			1		1	1					1	1	1	1	1	
47	Laboratoório Digital				1	1			1			1	1			1				1		1	1	1	1	1
48	Sistema de videomonitoramento					1	1	1		1	1		1	1			1			1		1	1	1	1	
49	CCO		1	1	1	1	1	1	1	1	1		1	1	1	1				1		1	1	1	1	
50	Programa Inovação		1					1		1	1		1		1	1				1		1	1	1		
	TOT.	6	17	15	21	21	18	34	18	24	32	8	50	17	11	42	20	10	3	34	13	50	50	47	40	8
	TOT (%)	12%	34%	30%	42%	42%	36%	68%	36%	48%	64%	16%	100%	34%	22%	84%	40%	20%	6%	68%	26%	100%	100%	94%	80%	16%

Appendix B - *Taxonomy, Business Model*

ID	Project	Business Model									
		Management			Infrastructure finant		Financial resources				
		Private	Public	Mixed	Private	Public	Private	Public			
1	Innovation for sustainable mobility and energy efficency		1	1	1	1	1	1			
2	Programa Nacional de Estratégias para Cidades Inteligentes S										
3	Wind Energy			1	1			1			
4	Digital Favelas		1		1		1	1			
5	City Operations Centre			1	1	1	1	1			
6	Planet SC/InLoop	1			1		1				
7	Urban Futurability		1		1		1				
8	Programa de Eficiência Energética	1			1		1				
9	Integração eletrônica transporte público		1			1		1			
10	Operação Caça vazamentos		1			1		1			
11	ônibus ecológicos										
12	ZUP		1	1	1		1				
13	Praça inteligente		1			1		1			
14	Internet Social		1			1		1			
15	Parquímetro Street		1		1						
16	Educação tempo integral										
17	Central de monitoramento			1	1	1	1	1			
18	Parceria Samsung			1		1	1	1			
19	FabLabs		1		1			1			
20	Rio Smart City			1	1	1	1	1			
21	WiFi gratuita		1		1		1	1			
22	CIGE			1	1	1		1			
23	luminárias inteligentes		1		1			1			
24	CCO			1	1	1	1	1			
25	ICI		1		1	1		1			
26	Bicicletário		1		1		1	1			
27	Playtown Recife		1		1			1			
28	Projeto bicicletas compartilhada		1		1		1	1			
29	Transforma Recife		1			1		1			
30	Cidade Cognitiva		1				1	1			
31	POADigital			1	1	1	1	1			
32	CittaMobi		1			1		1			
33	Ecoponto		1			1		1			
34	Parque Tecnológico		1		1			1			
35	Projeto Cidade Digital E Projeto Conecta			1	1		1	1			
36	Centro de Cooperação da Cidade		1		1	1		1			
37	Estação Digital Móvel		1		1		1	1			
38	Programa Municípios eficientes		1			1		1			
39	Polo Digital			1	1	1	1	1			
40	Soluções Ericsson Cidades Inteligentes			1	1	1	1	1			
41	Catador Digital		1		1	1	1	1			
42	Uso inteligente da água		1			1		1			
43	Monitoramento no parque da biodiversidade		1		1		1	1			
44	Conecta Cuiuabá - WiFi escolas			1	1		1	1			
45	Cisco Networking Academy	1			1	1	1	1			
46	Extreme Networks Caixa do Sul			1	1		1	1			
47	Laboratatório Digital		1			1		1			
48	Sistema de videomonitoramento		1			1		1			
49	CCO			1	1	1	1	1			
50	Programa Inovação					1		1			
	TOT.	3	31	16	36	28	25	47			
	TOT (%)	6%	62%	32%	72%	56%	50%	94%			

Appendix C - *Taxonomy, Purpose*



ID	Project	Purpose													
		Client			Product			Geographical target							
		Private	Public	Mixed	Specific	No Specif	Urban	National	Internatio						
1	Innovation for sustainable mobility and energy efficency		1		1				1						
2	Programa Nacional de Estratégias para Cidades Inteligentes S			1		1		1							
3	Wind Energy	1			1			1							
4	Digital Favelas			1		1	1								
5	City Operations Centre		1	1		1	1								
6	Planet SC/InLoop				1		1								
7	Urban Futurability			1		1	1								
8	Programa de Eficiência Energética	1			1		1								
9	Integração eletrônica transporte público			1		1	1								
10	Operação Caça vazamentos		1			1	1								
11	ônibus ecológicos			1	1		1								
12	ZUP		1		1		1								
13	Praça inteligente			1		1	1								
14	Internet Social			1	1		1								
15	Parquímetro Street	1			1			1							
16	Educação tempo integral		1			1	1								
17	Central de monitoramento		1	1		1	1								
18	Parceria Samsung			1	1		1								
19	FabLabs			1		1	1								
20	Rio Smart City			1	1		1								
21	WiFi gratuita		1		1			1							
22	CIGE			1	1			1							
23	luminárias inteligentes		1		1		1								
24	CCO		1			1	1								
25	ICI		1			1	1								
26	Bicicletário		1		1		1								
27	Playtown Recife		1		1		1								
28	Projeto bicicletas compartilhada		1		1		1								
29	Transforma Recife		1		1		1								
30	Cidade Cognitiva			1		1	1								
31	POADigital		1			1	1								
32	CittaMobi			1	1		1								
33	Ecoponto		1		1		1								
34	Parque Tecnológico			1		1	1								
35	Projeto Cidade Digital E Projeto Conecta			1		1	1								
36	Centro de Cooperação da Cidade		1			1	1								
37	Estação Digital Móvel		1		1		1								
38	Programa Municípios eficientes		1			1	1								
39	Polo Digital		1			1	1								
40	Soluções Ericsson Cidades Inteligentes			1		1	1								
41	Catador Digital		1		1		1								
42	Uso inteligente da água		1		1		1								
43	Monitoramento no parque da biodiversidade		1		1		1								
44	Conecta Cuiuabá - WiFi escolas		1		1		1								
45	Cisco Networking Academy		1			1		1							
46	Extreme Networks Caixa do Sul			1	1		1								
47	Laboratoório Digital		1		1		1								
48	Sistema de videomonitoramento			1		1	1								
49	CCO			1		1	1								
50	Programa Inovação		1			1	1								
	TOT.	3	28	19	26	24	43	6	1						
	TOT (%)	6%	56%	38%	52%	48%	86%	12%	2%						