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Smart Cities: Aspects to Consider for Building a Model from a City Government Point of View

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Abstract

This is a framework proposed to serve as an starting point to measure Smart Cities performance in accordance with their Smartness level. The academic development of this subject is still incipient and there is no sufficient data, information or validated knowledge to understand how the different variables of a SC operate. There is not a confirmed consensus on the definition of a Smart City (SC). Therefore, the model presented is a starting point for research, based on the study of the dimensions and KPI´s from field experience in many cities. Methodological aspects of the model will be analyzed in greater depth in subsequent works. At this stage, the authors have opted for developing a simple model so as to ensure it could be easily understood, managed and assimilated by the targeted audiences, that is to say, fundamentally those involved in city management.

1. Introduction

Over the last few years the Smart City (SC) concept has strongly emerged as a way to refer to cities primarily oriented to the development and massive utilization of Information and Communication Technologies (ICTs).

Nevertheless, the SC concept starts being used in a broader manner to allude to the special problems of cities related to issues such as environment, inclusion and usage of renewable energy, which have an impact in the long term and involve great urban planning efforts for the next 20 to 30 years.

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It is common for different specialists to stamp the concept with a vision inherent to their fields. Thus, for example, city planners tend to include, as the most relevant topics within the SC concept, those issues related to urban design and planning. However, to date it is not clear enough what a Smart City is. There is not an agreed definition or consensus over the dimensions or fields involved. There are no scientific papers referring to the subject or an accepted doctrine.

As there is no definition or consensus over the areas comprising a SC, there is no measurement system which allows us to identify and differentiate between a city and a SC, and to know the areas in which a city stands out from the rest in a methodical and organic way. These deficiencies, resulting from the incipient nature of this discipline as object of study, generate a lack of doctrine which has to be overcome.

Cites are acting as attraction poles for an increasing amount of people. They have turned into real innovation generators. City growth boosts economic development transforming cities into a tool that allows developing economies to reduce the breach in socioeconomic development.

Nonetheless, the present challenge is to achieve balance in the equation, so that the city can be turned into a growth generator for people that arrive to it in search of opportunities and not an unsuccessful experience resulting in a city that expels people.

According to UN Habitat, rising urbanization and per capita income go hand in hand for the world as a whole. As countries become more urbanized, both urban and national productivity will increase.[2]

Knowing the factors driving growth and innovation in the cities can be the key to promote suitable policies. The lack of doctrine and verifiable knowledge enabling the development of action plans is an issue that should be addressed by the academy, in coordination with the governments and companies, although this is a task requiring political articulation that can take several years.

[2] UN-Habitat, State of The World´s Cities 2012/1013, 2013

The central question I put forward and that I shall try to answer herein is whether it is possible to develop a SC indicator from available information, enabling the categorization of cities based on their Smartness level, and whether this kind of indicator can help us understand what makes a city Smarter than others, in order to know, study and replicate its good practices.

Another unavoidable questions shall be to define what a Smart City is, the dimensions comprising it, the elements integrating, in turn, each dimension, whether there is reliable information to measure each component, the degree of existing information and how to put together a measurement system with incomplete data and heterogeneous qualities.

The purpose of this work is to enable the construction of an information board that allows city managers to draw medium and long-term plans in a methodological order, intended to channel their cities towards a Smart approach.

2. The City as Growth Generator

The explosive growth of cities is among one of the most remarkable changes of this age. Urban population that by year 1800 represented 3% of the world population, by year 1900 amounted to 14%, in year 1950 amounted to 30% of the population, and to date represents 50% of the population[3]. As per World Bank's figures by 2012 world urban population represented, on average, 55% of the total population. For developed countries, these figures increase up to an average of 75%[4].

The information age and the process of ongoing change associated to it have a greater effect on urban life than ever before. There is an accelerated migration of people from the country to the city, seeking access to the amenities and services city life entails.

[3] Who´s Your City?: How the Creative Class Is Making Where to Live the Most Important Decision of Your Life, Richard Florida, Basic Books, 2009. chap. 2.
[4] http://datos.bancomundial.org/indicador/SP.URB.TOTL.IN.ZS

The effects of these migratory movements are therefore multiplied by the greater availability of information. Shorter and deeper economic cycles boost migration of people from underprivileged regions to those areas with greater job offerings, mainly in the cities. Now, migrations also take place from cities to cities.

This growth implies significant problems, as well as opportunities.

The cities are still the places where people cluster together to generate new ideas, knowledge and innovation. Income and productivity are higher in urban areas than in non-urban areas, maybe due to the fact that the average level of education achieved by people in the cities is higher than among non-urban inhabitants[5].

Growth strategies are no longer aimed at countries, but at cities. Not only companies, but also governments, need to know in depth which cities shall be the engines of the world growth.[6]

It is estimated that cities in the City 600 Index[7], that by year 2007 accommodated 20% of the world population, with a GDP of 30 trillion dollars, representing 50% of the world GDP, by year 2025 shall have an increase in their population of 1.6%, but with a GDP that will grow by 34 trillion dollars, achieving a 60% share of the world GDP.

The problems associated to this disproportionate growth in urban population are related, among other issues, to housing, and this is more remarkable in the cities of developing countries with lower levels of housing investment, with precarious and overcrowded accommodations and poor sanitary conditions.

Another problem is associated to the means of transport. Those cities designed several decades ago for a much lower number of inhabitants and vehicles are no longer capable of accommodating the volume of vehicles that doubles or triples over the decades.

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[5] Triumph of The City: How Our Greatest invention Make Us Richer, Smarter, Greener, Healthier and Happier, Edward Glaeser, The Penguin Press HC, February 2011. Cap. I, Education and Urban Success.

[6] Urban world: Mapping the economic power of cities, McKinsey Global Institute. R. Dobbs, S. smit, J. Remes, J. Manyika, C. Roxburgh, A. Restrepo, march 2011.

[7] McKinsey Global Institute Cityscope.

This larger volume of people and vehicles also has an impact on the environmental conditions, since waste generation increases in proportions that are difficult to manage, and the emissions from the means of transport based on fossil fuels also disrupt environmental balance.

Last and not least, security is another issue affected by increased crime rates.

Traditionally, city management only involved the administration of their physical space, being height, length and depth the dimensions in urban design.

Urban planning was the answer to prospective problems originated in the past, requiring long terms for its implementation. Likewise, a design flaw or an unexpected event took a long time to be overcome.

The issue of densification arises then as a concept and subject of discussion.

After all, a city is a place where people gather together, attracted by more and better opportunities, arising from the agglomeration, exchange and learning experiences that emerge from the dynamic interaction between its people.

If cities should be places with better living conditions implying superior economic results, it is only logical to reproduce the conditions therein to generate more and better interactions among their inhabitants and visitors, in order to expand and enhance their effect. Densification involves attracting and generating facilities for people to settle in the city. On the contrary, the trend observed in certain cases is towards a horizontal geographical expansion of the urban zones; this only brings more complexity in terms of management, costs and atomization of a city's vital energy. A modern city implies life and interaction outdoors.

3. The Virtual City

Better economic results and urban population growth also generate a change in the consumption patterns. There is a sharp increase in the demand for public utilities and transportation. There is also an increase in crime rates, in the total amount of motor vehicles, in the quantity of waste and residues generated, in air pollution and in housing problems, as well as an exacerbated pressure over green areas and public spaces.

It is at this point that technology arises as one of the most concrete opportunities to provide accessible solutions to improve the quality of life.

The opportunities currently offered by technology enable the incorporation of a fourth dimension, the virtual dimension, to the three existing dimensions of urban design: above ground, ground and underground.

Although it does not imply a journey in time, the technology available nowadays does make it possible to narrow distances significantly and have remote and real time access to information or people that are hundreds of miles away. Issues that not too many years ago demanded more time and efforts to get to the same results.

This opens up horizons to new businesses and markets. Nowadays, e-commerce is a billion dollar industry within the global trade. This large amount of transactions, that until only a few years ago required physical presence at a certain place for the execution of the operation, can now be executed online from home or a café. The virtual dimension also affects political processes. Nowadays, it is common to see how processes arising in an isolated manner are rapidly enlarged and expanded by the use of social networks, attracting supporters and generating mass movements in a few days or hours. The Arab Spring is an example of how a phenomenon of popular discontent can be virtually transmitted and expanded, making it even possible to overthrow governments.

Key decisions and planning in the management of city affairs were traditionally related to its physical space. Geography limited the possibilities and determined the development of the cities. At present, the virtual dimension demands a different approach and strategy, still related to the physical dimensions but with its own perspective.

The physical dimension of the city is subject to analysis, consideration and long-term planning. The effort implied in space intervention, to adapt a city to a changing reality, is considerable. The required investments are also significant. The virtual plane of city life development fully changes the time dimension of life perception, its problems and opportunities. In contrast to traditional urban planning, the planning of the virtual city is an almost meaningless practice that challenges administrators. Nowadays, things happen and change scenarios simultaneously, making it impossible to provide useful projections or true predictions.

Planning prompts a new discipline, the Big Data Analysis, through real time processing of large data sets, for the purposes of knowing the facts and trends as they occur.

Many urban and social solutions are rooted in the past. The repetitive cycle of city development based on a problem or new needs, the observation, analysis, planning and solution, may not be the suitable answer for the management of the virtual dimension.

4. Smart Cities

The Smart City notion is a new concept that started to emerge approximately two decades ago and was originally used to describe a city that applied technological solutions to the everyday problems of the city and its inhabitants, through the intensive use of information and technologies.

It was probably used in the first place by technology companies or divisions within larger companies, to refer to the range of products and services related to the application of technological solutions for the cities in a wide variety of issues.

Some authors consider it is a term used to refer to certain cities according to the use given to Information and Communication Technologies (ICTs)[8]. Nonetheless, it is still a quite confusing term that is difficult to define beyond the use and application of technologies[9].

However, P. Lombardi et al, in the quoted work propose a more comprehensive vision and consider that a city is Smart "…when investments in human and social capital, transport and ICT fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participative governance".

[8] An advanced Triple-Helix network model for Smart Cities Performance, P. Lombardi, S. Giordano, A. Caragliu, C. Del Bo, M Deakin, P. Nijkamp, K. Kourtit, International Journal of Electronic Government Research, vol. 2012, chap. 2.8.

[9] Using Classification and Roadmapping techniques for Smart City viability´s realization, Leonidas Anthopoulos and Panos Fitsilis, Electronic Journal of e-Government, Volume 11 Issue1 2013, p.326 – 336.

In recent years, SCs started gaining a new impulse. The greater challenges, and the variability and intensity of current city problems are making mere flaws in the planning processes, that failed to provide solutions to everyday city problems, to be now transforming into problems of such a magnitude that require a different approach.

Climatic change is speeding up and is no longer a simple catastrophic theory, but a concrete reality showing its effects at a daily basis through climate events.

Likewise, the environmental impact of exploitation policies that did not take into account its preservation, coupled with the social problems related to strong migratory movements, have rendered obsolete the public management techniques that were in force for many years.

Opportunities delivered by technology complete the picture that triggers the need to find tools for the improvement of city life management on behalf of local governments, including strategic planning.

Literature provides varied definitions of SC.

According to the European Smart Cities Model, a Smart City is a city well performing in the six axes of the model it puts forward: Economy, Mobility, Environment, People, Quality of Living and Governance[10].

Edward Glaeser, in his book "The Triumph of the City…" already expresses a lot in the title about what he believes is a SC, and comments that the "smartness" of a city is linked to its people rather than to its building infrastructure[11]. Then, he deepens the concept by referring to the city of Singapore, the success of which he attributes to its strong investment on education.

Later on, he comments: "The single best way to create a smart city is to create schools that attract and train able people".

[10] www.smart-cities.eu/model.html

[11] Triumph of The City: How Our Greatest invention Make Us Richer, Smarter, Greener, Healthier and Happier, Edward Glaeser, The Penguin Press HC, February 2011. Cap IX How do cities succeed: Singapore & Gabarone.

Others consider that a Smart City is a city that is really concerned about environmental care and preservation. However, there are other authors, such as Richard Florida, who analyze cities in the light of their creative capacity, through the three Ts' model: Talent, Tolerance and Technology[12].

In his book, Florida introduces the concept of "creative class" and how it gathers and binds together around certain regions or urban centers having some features in common, in connection with their levels of tolerance, the use of technologies, measured through the quantity of people employed in technological industries, and how these regions and cities have superior levels of economic performance.

Although Florida does not use the term SC, indeed he refers to "Mega regions", his analysis is very enlightening and in line with what we consider to be the innovation component in a SC.

In this same line, in the already quoted work of P. Lombardi et al., the value of the production of knowledge is highlighted as a basis for a SC measurement and assessment model. Thus, they propose to use the Triple Helix model of Henry Etzkowitz[13], adding to the original "helices", University, Industry and Government, three new components, such as level of education achieved by workforce, knowledge through the registered invention patents indicator and market force, measured by per capita GDP.

As stated above, there is still no consensus on the definition of a SC.

However, it is a discipline arising great interest and representing considerable opportunities in the academic level to contribute to the vision and knowledge of people and institutions acting on the cities ecosystems. The concept of Smart City leads to a new area of knowledge that envisages many potential lines of research and development and that goes well beyond what has so far been a strictly spatial perspective on city planning and design.

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[12] The Rise of The Creative Class, Richard Florida, Basic Books, 2002, chapter 14.

[13] The Triple Helix: University-Industry-Government. Innovation in Action, Henry Etzkowitz, Rutledge, 2008.

A Smart City is much more than an intelligent city. It is a dynamic and agile city, able to anticipate and exceed the expectations of its inhabitants and users.

It is a city that learns and generates permanent feedback. It is constantly improving and innovating. It is also an efficient city, concerned about development and inclusion. It is a city interested in environment, culture and participation. It is a sustainable city.

This does not mean it is free of problems. Conversely, it does have to face a great deal of issues. But they are addressed in new and innovative ways, transforming them in opportunities to learn and improve. It is a responsive city.

6. Smart City Indicator

The Smart City is a concept that describes a city based on its capacity to innovate and use technologies to improve the quality of life of the people who live in or use it.

A SC is made up of three dimensions: People, Habitat and Government.

People are the ultimate users of a SC, but they are also the essential element of the constitution of the city. People represent the component that really shapes the city, far beyond its physical dimension. People include inhabitants and individuals who go on a daily basis to the city for work or tourism, or who simply go through it, using its services and infrastructure.

The Habitat is the physical platform where city life takes place, and which, through design and planning, can either expand the range of solutions and possibilities to improve the quality of life in the city, or narrow them.

The Government is the entity setting up and enforcing the legal framework, which coordinates the policies to promote order, reach consensus and enhance conditions so that a SC can act as an effective instrument to improve the quality of life therein. These three dimensions are enhanced by a fourth dimension: the virtual dimension.

This fourth dimension is the one that boosts the aforementioned ones, achieving geometrical increases in the capacity of a city to improve its living conditions.

Smart City Index:
SCi= (P + G + H) * I
P: People
G: Government
H: Habitat
Iict: Innovation and Technology Multiplier

The SC Indicator is a composite indicator in base ten, used to perform comparisons between cities to determine their strengths and weaknesses, through the separate analysis of its components. It consists of three dimensions and a multiplier factor. Each dimension and each component of the multiplier consist, in turn, of axes, which are made up of factors that are formed by indicators.

The indicator shall have the following characteristics:

Composite: it is an index made up of different indicators referring to different domains.
Permanent: the index is aimed at long planning horizons, so its composition must reflect information of verified indexes, used throughout time.
Homogeneous: its indicators must be balanced regarding their date of collection; indicators of varied dates should not be combined.
Traceable: the index must be able to show the evolution of the measured object through time and in variability conditions.
Dynamic: it must adapt methodologically and, as it is aimed at long planning horizons, it must consider the methodological adjustment keeping its traceability.
Composition: it shall mainly consist of quantitative indicators.
Origin: it shall mainly consist of primary indicators.
Universal: it must be useful to measure and compare any type of city, regardless of their size and geographical or political condition.
Simple: understandable information that can be comprehended by everyone shall be methodologically prioritized.
Open: baseline information and the methodological aspects shall be available for any person intending to analyze them.

According to this last criterion, both the model itself and the indicators integrating it should ideally come from open databases, in compliance with the Open Data principles, to wit:

1. Fully available, meaning that information should be totally accessible and not biased.
2. Primary sources, equivalent to collecting information from the source itself, with the fullest details as possible.
3. Reusable; this means that it is possible to process it and to extract additional information from the provided data.
4. Information must be timely.
5. Information must be fully accessible and preferably freely available in Internet.
6. Non-discriminatory towards people or groups of people and not limited by technological issues.
7. Free and non-licensable.

For more information, see the criteria and recommendations in:
http://globalopendatainitiative.org/

7. The Model

The definition of the extent of a Smart city is like the measurement of happiness. What is the measure of happiness? Is there a happiness scale? For example, can we talk about a 6.4 or an 8.5 degree of happiness? However, many years ago Aristotle concluded that happiness is virtue. Can we say virtue in a city would consist of achieving quality of life for its citizens and users?

Now, establishing quality of life is more than establishing the GNP, or per capita GDP, or its growth. Thus, we need a model that helps us understand and see the complexity of the factors that make up city life in a comprehensive way.

To understand this, we need to break down the reality into many dimensions that help us realize our strong and weak points, where we are doing things right even though the situation is bad, in which areas we are not doing enough, and where we have opportunities.

Besides, as we do not have a parameter to determine when we are in a good or bad condition, we need to make comparisons, or assess in relative terms each dimension of the model with other models or cities in order to have good examples so as to understand, learn and imitate the good practices.

There are many reports and statistics about cities. Assessing cities and building up rankings is a very appealing activity that arouses great interest. There are companies that decide upon the location of their offices, plants and executives based on currently available studies about cities. Also investment decisions, mainly in real estate, are taken based on these statistics.

There are extensive reports on partial aspects or components of what we consider to be a SC perspective, which require a wider and more comprehensive approach.

We can mention as the most renowned Indices, the Green City Index that, under Siemens' sponsorship, develops a ranking of cities focused on their environmental sustainability.

The "Liveability Index" of the Economist Intelligence Unit is another very interesting index because of its comprehensive approach and the quantity of cities included.

There is also the Mercer Quality of Living Worldwide Ranking that provides information on 460 cities around the world. And finally it is important to be mentioned that the International Standardization Organization (ISO), has recently published a new standard, the ISO 37120:2014, on Sustainable Development of Communities that propose and defines a set of indicators to measure city services and quality of life.

Despite these interesting studies, we think there is a lack of an integral statistical point of view that measures a Smart City with the comprehensiveness and overview of the elements that constitute it.

The existing models or reports are partial as far as they cover one aspect of the city and they are frequently based on qualitative information or opinions from experts that are not verifiable.

In general, the information on the methodological aspects is not verifiable either. A core difference among the available rankings and the methodology we propose in this paper lies on its purpose.

In this paper, we propose a model that serves as a city planning tool rather than a consumer good aimed at entities or people that as city users have to take decisions based on different time horizons and aspects.

We also consider that a statistical analysis of this nature should provide information on the sources and selection criteria adopted on the component indicators and on the qualitative assessment criteria followed.

One important problem we find working with cities is the inexistence of verifiable and primary hard data related to cities. So any measurement system proposed has to take this reality in consideration, beyond the desire or the intention to have a perfect model. We think the model has to be feasible from the information avalaible first.

8. How the Model Works

In annex A, we provide details on how each dimension is structured, with their axes and factors, as well as the indicators we recommend for the quantitative assessment of each factor.

This model has two readings. One of them derives from strict calculation of the recommended indicators. Calculations have some simple rules we have imposed to highlight or penalize certain aspects referring to baseline indicators.

The first rule refers to the date of indicators, and so as not to favor the calculation of the SCi with old information, we have considered penalizing the indicators when they are older than 2 years by multiplying the value of the indicator by a factor of 0.95 for the third year as from the estimation of the SCi, 0.90 for the fourth year and 0.85 for the fifth year. As from that year, indicators are always calculated rectified by factor 0.85.

The second reading of the model is the one arising from the qualitative assessment of factors.

We understand that the reality of a city is very complex to try to understand it and, least of all, to try to act on it based on a handful of indicators.

We do think it is necessary to perform cuts and periodic measurements and comparisons with other cities to see where we stand, where we are going and at what speed. But as recommended by the good management practices, the indicator is a good instrument to provide information on reality, but in no way reality is explained by one, two or a thousand indicators.

Then these two readings refer to different scopes. For external purposes and to perform relative assessments comparing them to others, it is fine to standardize and make comparisons based on hard criteria with delimited interpretations. In our opinion, it is important also to establish standards for each single indicator and that standards have to result from an independent analysis of the real measures provided by the survey. For example, if we consider the Air Quality Factor and its indicator the Suspended Particular Matter in a city we have to consider that there exists a standard established by the World Health Organization that specify a minimum standard of 20 ug/m^3 in an annual average[14]. So that measure would be the average rate in the indicator metric scale. Any value assessed for a city has to be standardized according to that average value.

For internal purposes and to perform a deeper analysis based on the clues provided by indicators, soft, subjective information shall have to be collected, from the opinion of experts and people involved in management of processes related to each indicator. This survey must be broad and reviewed in detail so as to reach a diagnosis that completes the opinion and trend suggested by the indicator.

In this case, and for non-existent, difficult to find or unreliable indicators, we propose that qualitative analysis rules have to be defined and be published to guide the opinion of experts and to be used as a basis to compare the indicator to be evaluated among different cities, so as to perform a qualitative assessment with some degree of rationality and proven comparison power.

[14] Organización Mundial de la Salud, Guías de calidad del aire de la OMS relativas al material particulado, el ozono, el dióxido de nitrógeno, y el dióxido de azufre (2005).

For this analysis, we consider it useful and comprehensive to perform an analysis based on detailed factors that we believe describe perfectly well the complexity and varied issues of a SC.

The model is not very sensitive to variations in an individual indicator, since this is the effect when it is made up of 40 indicators that are all equally weighted. As it is an experimental model, practice and opinion of those who use the indicator will vary its composition and adjust it to reality. That is why we consider in this development stage not to weigh individual indicators, so as to keep traceability of the SCi.

We understand that the experience and the use of this tool shall begin yielding information to correlate the variables with respect to each other and with other variables, so as to establish weights as appropriate.

1. Conclusion

This model is not the final model, but is the initial step to achieving a more "scientific", more quantitative, more comprehensive and more transparent way of measuring cities at their smartness level.

We are testing the model and in that way we have made an integrity and methodological test over the city of Buenos Aires with the following findings:

- Only 2 indicators, over a total of 40 were not found and were evaluated using a qualitative tool as that mentioned in page 22, referred to a self-assessment methodology.
- All the 38 indicators found were from primary sources.
- Over the 40 indicators, just 9 were not available from public and open sources.
- The average antiquity of the indicator is two years.

We find this model describes the broad and complex reality a city government may face to understand and define a Smart City agenda, identify the areas of opportunity, to compare with and learn from others and to develop the necessary tools to become smarter.

We also think this model provides us a detailed framework for the analysis, at a micro level, of where the final causes of the trends and waves that move a smart society lay, which have to be studied, correlated and discovered.

More field analysis is waiting to come, and the findings will be shared with colleagues and published in specialized journals.

In this moment many international organizations, as ISO and ITU, just to mention many of them, are working in the development of broad models and standards to measure Smart Cities. As in the model I am proposing here, those efforts are to be finally shaped, by the definite field experience.

So we have to wait and to make the correct experimentations to arrive to the final model. This model I am proposing is the most clear and simplest way to measure a City from the point of view of the possibilities and limitations and difficulties that cities government have. But this will be the subject for a next paper.

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Annex A: **Description of Dimensions, Axes and Factors**

1. People Dimension

A SC is made up of its people, as a result of a dynamic interaction that combines cultures and ideas to produce better results and further development. This dimension measures vitality and dynamics of a city through its level of inclusion and tolerance. A SC is an enclave that attracts people, links them and produces better results in terms of development and quality of life.

1.1. Society axis: people are the driving force of a modern city. Their dynamism and development determines the velocity of change. Openness and tolerance are the fuel that encourages and drives the society to sustainable progress through the exercise of diversity that streamlines the incorporation of the new aspects.

i. Education factor: it is the level of educational development and the degree of evolution in digital education achieved, on average, by the population of the city.
Indicator: percentage of inhabitants holding a university degree.

ii. Diversity factor: it is the capacity of the society to join together people with different cultures and ideas, achieving a unique identity.
Indicator: percentage of inhabitants of foreign origin.

iii. Inclusion factor: it measures access to education and formal employment of people with disabilities, immigrants and those with low income.
$Indicator_1$: percentage of people with disabilities and with formal employment.
$Indicator_2$: percentage of people with disabilities holding a university degree.

iv. Inequality factor: it refers to the dispersion of income level.
Indicator: Gini index.

1.2. Quality of Life Axis: the central result of a SC is measured according to the quality of life of its inhabitants and users, that is superior and with sustainable growth.

i. Culture factor: it takes into account cultural offerings as well as the possibilities of having access to them.
$Indicator_1$: number of people attending cultural events.
$Indicator_2$: private and government annual expenditure on culture as a percentage of the Gross Geographic Product (GGP).

ii. Health factor: it assesses the health care system through life expectancy at birth.
Indicator: life expectancy at birth.

iii. Housing factor: it assesses the number of people living on precarious housing conditions, without access to basic utilities, and housing deficit.
$Indicator_1$: number of people per room.
$Indicator_2$: availability of basic utilities.
$Indicator_3$: number of household owners.

iv. Security factor: it assesses the level of personal security through crime rates, road accidents and damages related to natural catastrophes.
Indicator: number of homicides for every 100,000 inhabitants.

2. Government Dimension

The role of governments in a SC is a key enabling or inhibiting factor of people's energy towards innovation and development. The municipal state is the government stratum that is closer to people; thus, it has better possibilities of identifying their needs and of being aware of the problems within the city.

1. Infrastructure axis: the main function of the government is to provide a suitable and modern platform for the socioeconomic development of the SC.

i. Connectivity factor: it is the provision and facilitation of the necessary means so that everyone can have access and use the ICTs.
Indicator: area covered by public WiFi.

ii. Human capital factor: it refers to the level of efficiency of city government human resources, expressed in their productivity and level of job satisfaction.
Indicator: percentage of city budget allocated to administrative staff salaries.

iii. E-management factor: it measures the usage of new technologies on behalf of the city government for its own governance.
Indicator: number of procedures performed online.

2. Services axis: it refers to the offer of resources by the government to facilitate its relationship with citizens, either for services and procedures or for citizen initiative and involvement in public affairs.

i. Procedures factor: number and variety of online services offered by the government.
Indicator: number of online procedures compared to the total amount of procedures.

ii. Citizen involvement factor: it assesses the availability of resources and the volume of initiatives generated by people and implemented by the government.
Indicator: number of people involved in participation platforms.

iii. Open government factor: it measures the quantity, quality and level of usage of the data offered by the government.
Indicator: number of available reusable government databases.

3. Habitat Dimension

A city is smart from the point of view of environment and resources, as long as it is sustainable. That means that it should actively seek and encourage its preservation and care, anticipating and planning actions and legislation. Furthermore, and given the fact that sustainability requires full commitment on behalf of the government and its inhabitants, awareness and cultural change must be encouraged, supporting the concept and projecting it in the future.

1. Environmental axis: it refers to the level of development in the use and application of measures towards environmental preservation and their outcome.

i. Sustainable energy factor: it measures the usage of clean energies and renewable sources.
Indicator: percentage of energy consumed from non-contaminant sources.

ii. Waste management factor: it assesses the total volume of generated waste, the recycled portion and whether there is some kind of monitoring for its smart collection.

Indicator$_1$: amount of waste generated per inhabitant.
Indicator$_2$: percentage of recycled waste.

iii. Air quality factor: it refers to the policies for the management of air pollution, their results and the level of particulate matter in the air.
iv. Water management factor: assess the consumption level of water by the population and its proportion of recycled waters.

Indicator: ratio of airborne particulate matter.

2. Mobility axis: in a modern city, mobility is provided by an efficient public transport system, minimizing transport times through smart management of transport network, encouraging people to live the experience of commuting through the city. It is supported by technology, so that people can assess and take decisions on the best possibilities of transport, either public or private, maximizing their wellbeing.

i. Clean transport factor: it refers to the priority in the use of clean energies for the city public transport and for the fleet of governmental vehicles.

Indicator: percentage of public transport that does not give off polluting gases.

ii. Multimodal access factor: it is the provision of safe alternatives to travel across the city to inhabitants and visitors, combining different modalities in an organized and efficient way.

Indicator: percentage of people using public transport.

iii. Commuting time factor: it is the average time it takes to commute at a daily basis from home to work or everyday activities.
Indicator: average daily time required by people to commute to work.

3. Urban planning axis: it is the design and planning of the city physical space, taking into consideration its sustainable development and preservation of cultural and urban patrimony.

i. Green space factor: it assesses the ratio of total city space that will be used for green spaces and its accessibility level.

Indicator: surface area of public urban green spaces per inhabitant.

ii. Public space factor: it measures the ratio of public space in relation with the built up space.

Indicator: built up area on useful public space.

iii. Density factor: it measures the level of geographical dispersion of the city inhabitants.
Indicator: number of inhabitants per km^2.

4. Economy axis: it is the creation of a framework encouraging innovation, initiative and the development of new productive activities in an inclusive way and integrated to trade flows and worldwide change trends.

i. Productivity factor: it is the production rate per person; the volume of employed individuals.

Indicator: it measures gross product of the city per inhabitant.

ii. Employment factor: it refers to the job opportunities and quality of employment of the city inhabitants.

$Indicator_1$: average income per person.
$Indicator_2$: rate of formal employment.

iii. Global and local connection factor: it measures participation of tourism and external commerce in the economy of the city. $Indicator_1$: quantity of foreign visitors in relation with the city population.

$Indicator_1$: quantity of tourists visiting the city.
$Indicator_2$: percentage of city exports over GGP.

4. Multiplier of Technology and Innovation

In a SC the capacity to assimilate new technologies and transform them in opportunities for people is an essential feature. This multiplier represents the fourth dimension of a SC projecting the result of the previous dimensions, achieving the geometrical enhancement for providing opportunities and improving the quality of life of citizens and users.

1. ICTs axis: it is the degree of application and penetration of new technologies in a SC, which is the result of an installed technology and of the capacity of the people to have access to that technology.

i. Accessibility factor: it measures the quantity of people with access to network connectivity and the digital inclusion of low-income people.
$Indicator_1$: number of households with broadband internet connection.
$Indicator_2$: number of inhabitants with a Smartphone.

ii. Capacity factor: it refers to the quality and dimensions of the city technological infrastructure, enabling access to ICTs.
$Indicator_1$: mobile network connection speed.

2. Innovation axis: it is the quantity and variety of innovative ideas. It is the driving force of the SC since it broadens the productive possibilities frontiers and is a source of higher life quality.

i. Creative industries factor: it is the involvement in the GGP of activities related to creativity and innovation.
$Indicator_1$: percentage of the GGP corresponding to the cultural, technological and engineering industries.
$Indicator_2$: number of invention patents approved per inhabitant.

ii. Entrepreneurship factor: it is the level of development achieved by the entrepreneurial activity in the city.
$Indicator_1$: number of new registered companies.
$Indicator_2$: percentage of the city budget allocated to encourage entrepreneurs.