Abstract

Objective: The main objective of the study is to deepen the concepts of Smart City and Sustainability to propose a Sustainable Smart City model for the areas of Economy, Government, Environment, Mobility, Smart Society and Quality of Life.

Methodology: To achieve the main objective, a review of the existing scientific literature on smart Cities, sustainability and its areas of influence and indicators has been carried out. Subsequently, an analysis of three Smart Cities was made and, finally, a proposal for a Sustainable Smart City model was made.

Results: Several indicators have been presented for the six areas: Economy, Government, Environment, Mobility, Smart Society and Quality of Life. These areas allow improving and facilitating the quality of life of its citizens while maintaining a balance between the economic, social and environmental fields. In addition, a model is proposed for each area that includes sustainability.

Limitations: The formulation of the Sustainable Smart City model has not considered the cost of applying the indicators presented for the area.

Practical implications: Among the contributions, the formulation of the concept of Sustainable Smart City stands out, as well as its indicators. Finally, a Sustainable Smart City model is projected according to the above presented.

Keywords: Smart City; Sustainability; Economy; Society; Environment.

JEL codes: O33, L91, L96.

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在发展可持续智慧城市中信息及通信技术之应用

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文章摘要
研究目的：本研究的主要目的为深化智慧城市和可持续性的概念，从而在经济、政府、环境、流动、智慧社会以及生活质量范畴提出一个可持续智慧城市模型。

分析方法：为要达到主要目标，研究对有关智能城市、可持续发展及其影响范围和指标的现有科学文献进行了回顾。随后，研究对三个智慧城市进行了分析，并提出一个可持续智慧城市的模型。

研究结论：结果针对六个范畴提出了一系列的指标：经济、政府、环境、流动、智慧社会以及生活质量。这些指标可以改善并促进其公民的生活质量，同时能够在经济、社会和环境之间取得一个平衡。此外，文章针对每个范畴提出了一个涵盖可持续性的模型。

研究局限：研究在制定可持续智慧城市模型时，并没有考虑到在每个地区要应用那些指标时的成本。

实际应用：在众多贡献当中，可持续智慧城市的概念以及其指标的角色尤其重要。最后，文章根据上述的研究内容归纳并得出一个可持续智慧城市的模型。

关键词：智慧城市、可持续性、经济、社会、环境。

JEL 分类号: O33、L91、L96。

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1. Introduction

Population in cities is projected to increase from 3.5 billion to 5 billion by 2030; this means increasing the needs of residents as among others, the energy consumption that today is between 60 and 80% of the total (United Nations, 2020).

To meet the current needs of the population, cities will need to undergo a transformation in which they work for the main problems faced today by human beings such as: poverty, climate change, health care, education and equal diversity, whether gender, race or age among others (Sonsino & García, 2020). The need for developments in cities has attracted the interest of the public and private sectors in developing strategies that are successful in the face of conflicts and thus leading the rankings of large cities in the world (European Environment Agency, 2015).

The transformation claimed does not involve building the city again, but from the adoption of endogenous resources, future challenges will be solved (De Pablos Heredero et al., 2017). The transition requires the application of concepts such as sustainable consumption, which reduces needs and consumption (Fernández Güell, 2014); the circular economy, where the life processes of factors are lengthened and emissions reduced; and, the consideration of the blue economy model, which seeks ecosystems existing in nature that are more efficient (Norma Martínez and Porcelli, 2018).

According to current times, there are means that help the region achieve the necessary commented transformation. These means correspond to Information and Communication Technologies, here in after ICTs, which requires of a complex activity due to various factors such as access and availability of resources or lack of digital skills in certain groups of persons. These limitations must be considered in each consistory of the city as well as from the population, who are active in the implementation of the new development of the region, either participating in mobility or environment initiatives.

The new development cited is called Smart City. The aim is to improve the quality of life of the citizens who reside it as well as to contribute to the creation of inclusive, safe, resilient and sustainable spaces in areas such as the economy, the social and the environment (United Nations, 2020).

Therefore, the general objective of this work is to deepen the knowledge of Smart City and Sustainability and to propose a model of Sustainable Smart City to satisfy and improve the quality of life of citizens. Taking into account the areas of development of a Sustainable Smart City (Economy, Government, Society, Quality of Life, Mobility and Smart Environment) a number of indicators and the use of ICTs are proposed to improve and facilitate the quality of life of its citizens, while maintaining a balance between the economic, social and environmental fields.
2. Conceptual Framework

A review of the concepts of Smart City and Sustainability has been carried out, in addition, it has delved into the main dimensions and indicators that make up a Smart City.

2.1. Smart Cities and ICTs

In the coming times an increase in the population of cities is expected, a reality that is much closer to be faced and overcome, otherwise there would be great risks due to a disorderly growth of the inhabitants of one region and the emergence of social, economic or environmental problems among others.

There are many definitions of Smart City since the beginning of the concept, such as the use of ICTs for the benefit of inhabitants (Klein & Kaefer, 2008); the integration of technologies into urban processes and services oriented to achieve efficient development (Fernández Güell, 2014) or the combination, in a clever way, of the citizens’ resources and activities. Belissent, Mines, Radcliffe & Darshkevich (2010) stated that “a Smart City is one that uses ICTs to have infrastructure and services in a city such as the administration, education, healthcare, security, transport and public services, making them more aware, interactive and efficient”. It disposes and uses the best ICTs to improve the quality of life of its inhabitants and facilitate it, while trying to combat the challenges present in society through infrastructure (United Nations, 1987).

The Smart City is the city of the future. It is recognized from an innovative environment and requiring the participation of various agents of a public and private nature, as well as the influence of the business environment, with which to create businesses in any of the sectors present in the region. This purpose requires the use of ICTs to support planning and control processes, resulting in real-time data from heterogeneous sources. These are processed by systems, organizations, and value chains that optimize them. Some noteworthy ICTs functions are presented as indicators in a Smart City such as: Wi-Fi connections, pollution control sensors or the digitization of public administration between other. Examples of ICTs are: CODEX platforms and SNSP sensors in Singapore, Talk London system or New York’s Domain Awareness System (DAS) server.

Figure 1 shows the total number of documents that study and analyze Smart Cities from the Web of Science database. To do this, the search has been refined in articles, papers, book chapters and magazines.
Six areas of study have been determined in a Smart City: Government, Economy, Quality of Life, Society, Mobility and Smart Environment. Each group will in turn present indicators that measure how a city is “smart”. There are also several rankings that classify Smart Cities according to the qualifications received by their citizens in each of the subjects for which their needs are met such as IESE Business School (2020), Financial Centre Futures (2020) or Mori Memorial Foundation (2020).

2.1.1. Dimensions of Smart Cities

According to ISO 37120, which describes the rapid growth that cities will have in terms of population, 70% of the world's inhabitants are expected to live in cities by 2050. This fact requires areas or groups in which to meet the needs of the present and future population (International Organization for Standardization, 2018).

Following Belissent, Mines, Radcliffe & Darshkevich (2010), the application of ICTs in Smart Cities can be carried out in areas such as administration, education, healthcare, public safety, transport and public services. While these may generally be the ICTs measurement categories for a Smart City. However, in 2011, Boyd Cohen designed The Smart Cities Wheel, which proposes six more specific groups and, in turn, names a set of categories in which to apply a series of indicators in which to measure the degree of Smart City (Figure 2).
Thus, Monfaredzadeh & Berardi (2015) defined the six groups in Figure 2:

- **Smart Economy**; linked to innovation, business entrepreneurship or labor market flexibility.
- **Smart Mobility**; related to the accessibility, security, time and management of transport technologies.
- **Smart Governance**; related to citizen participation in the decision making of a government, transparency of government...
- **Smart Environment**; associated with lack of pollution or reduction of carbon footprint.
• Smart Quality of Life; fully associated to the quality of life of the citizen.
• Smart Society; linked to the level of qualification of human and social capital, as well as creativity and tolerance between people.

Others such as Ahvenniemi, Huovila, Pinto-Sepp & Airaksinen (2017) or ITU (2014), also support the presence of the six domains described. Meanwhile, the Institute for Urban Strategies founded in 1981 under the Mori Memorial Foundation (2020). This program was among the first to introduce meters for Smart Cities. It coincides in one of the areas described as Economy, Quality of Life, Mobility and Smart Environment; but the rest are attributed to Research and Development where they take into account the investment in R&D; and Cultural Relationship that counts the number of tourists or hotels available, among others.

2.2. Sustainability

The presentation of the concept of Sustainability took place in the last century when, in 1987, the Brundtland Report was prepared by World Commission on the Environment and Development, hereinafter WCDE, by the United Nations in 1987. The WCDE addressed two main objectives: the situation of poverty in many countries and the environmental problems that would be to come in the face of the actions implemented by society at present. This report called for action by the governments of major countries to solve problems such as population and human resources, energy, industry, food or urban challenge in cities. Thus, in order to present a common term with previous issues in a single action, the concept of sustainable development was born defining itself as “the development that guarantees the needs of the present without compromising the possibilities of future generations to satisfy their own”. However, following the Rio Summit held by the United Nations in 1993, two interpretations of the same concept emerged due to economic inequalities between rich and poor countries. This fact was due to the sense of the concept of development, as it constitutes a confrontation between those who conceive it as an economic growth, compared to those who understand a qualitative improvement and potential of resources, and not quantitatively, in line with the care of the environment (Rodríguez Pérez de Agreda et al., 2019).

Over the years, environmental and social degradation became relevant and, in 1992, the WCDE developed Agenda 21 (United Nations, 1992), which established an action program for United Nations member countries. Its objective was to promote sustainability, that is, to nurture indicators that safeguard the environment in cities, thus fighting social inequalities. Subsequent events, congresses and fairs demonstrated that cities are the main agents by which environmental and social problems are increased, as recounted at the meeting held by the International Telecommunication Union, hereinafter ITU, in Geneva in 2006. This conference served, to highlight that cities are the cause of the above conflicts, but also, that in them is
where the solutions to suppress inequalities reside through the commitment of ICTs (ITU, 2006).

Thus, to a greater extent, the unique concept of Sustainability is addressed, that is, the protection of the environment around us, managing to avoid greater damage that, perhaps, in the present is nonperceived, but do so in the future.

With cities, the solution to the social and environmental conflict that arises is to be expected that according to the current situation in which it is immersed in the continuous technological revolution, they will build up and evolve into Sustainable Smart Cities. They will improve and facilitate the quality of life of all its inhabitants regardless of the economic range, applying ICTs, in line with the care and attention to the environment and the possible effects that may arise from this transformation and that are derived from generations to come.

Adding the term Sustainability to Smart City implies greater emphasis on three global dimensions according to the ITU report (2014):

- Environment and sustainability. Where environmental, economic and social aspects are addressed, without damaging the physical and biological surroundings of a city.
- Levels of city services. It explains the different services that a city offers to its inhabitants through government, sustainability, technologies or the economy.
- Quality of life. Referenced to the multiple lifestyles that residents lead in a city and in the way of perception of well-being.

Finally, fundamental factors for the livelihood of a Sustainable Smart City are summarized in five, each integrating and related to the three global dimensions: Economy, Government, Environment, Mobility and Society, where it integrates in the latter the Quality of Life (ITU, 2014). While Petrova-Antonova & Ilieva (2018) support the five groups cited with the difference that Quality of Life counts Society as an independent one.

3. Methodology

A systematization of quality indicators has been performed from a bibliometric analysis. To this end, it has been categorized by dimensions such as: Economy, Mobility, Environment, Government, Quality of Life and Society. In addition, the most relevant attributes of each and the reference authors from which they come from, have been established.

In a second stage, three city cases have been selected, which have been analyzed individually. For the latter case, a non-parametric test has been developed using a categorical independent variable and a quantitative dependent variable to compare samples. The test includes the descriptive statistics and the Kruskal – Wallis test that allows to accept or reject the null hypothesis in which the distribution for each city is the same among the categories.
Finally, a Sustainable Smart City model is proposed based on the above information.

3.1. Bibliometric analysis

To know how a region is considered a Sustainable Smart City, account must be taken of the indicators they have used in each of the areas. These indicators must comply with ISO 37120 by contributing to the 2030 Agenda objectives presented at the Sustainable Development Summit in New York (United Nations, 2015) and being the main:

- Objective 3, in defense of a healthy life promoting well-being in all ages.
- Objective 4, ensuring inclusive and equitable education equally for all.
- Objective 6, providing and sustainably managing water use.
- Objective 8, promoting sustained, inclusive and sustainable economy.
- Objective 11, making cities inclusive, safe, resilient and sustainable.
- Objective 13, combating climate change measures and their adverse effects.

The following, Table 1, shows the most common set of areas and indicators.

Table 1. Dimensions, categories and indicators for a Sustainable Smart City II

| DIMENSION | CATEGORY/ATTRIBUTES | INDICATOR (units) | SOURCE |
|-----------|---------------------|-------------------|--------|
| Economy   | Productivity        | Patents per year (%) | Bosch et al. (2017), ITU (2014), Mori Memorial Foundation (2019) |
|           |                     | Gross Domestic Product, GDP (€) | Bosch et al. (2017), ITU (2014), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018), Voda & Radu (2018) |
|           |                     | Unemployment rate (%) | Bosch et al. (2017), ITU (2014), Petrova-Antonova & Ilieva (2018) |
| Opportunity | Start-ups (%) | Alvarado López (2017), ITU (2014), Petrova-Antonova & Ilieva (2018), |
|           | Research and development (% of GDP invested) | Alvarado López (2017), Bosch et al. (2017), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018), Voda & Radu (2018) |
| DIMENSION | CATEGORY/ATTRIBUTES | INDICATOR (units) | SOURCE |
|-----------|---------------------|-------------------|--------|
| Mobility  | Efficient transport | Accessibility to public transport (Likert 1-5) | Bosch et al. (2017), ITU (2014), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Mobility  | Efficient transport | Density of public transport network (m/km²) | Bosch et al. (2017), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Mobility  | Multi-modal access | Travel by public transport (%) | Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Mobility  | Technological Infrastructure | Access to real-time information (Likert 1-5) | Bosch et al. (2017), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018) |
| Resource management | Total energy consumption per inhabitant (in MWh) | ITU (2014), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Resource management | Local renewable energy (in MWh) | Bosch et al. (2017), ITU (2014), Petrova-Antonova & Ilieva (2018) |
| Environment | Water consumption (% in m³) | ITU (2014), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Resource management | Reused water (% in m³) | ITU (2014), Petrova-Antonova & Ilieva (2018) |
| Resource management | Emissions of NOₓ (% in tons) | ITU (2014), Petrova-Antonova & Ilieva (2018) |
| Resource management | Annual household waste per inhabitant (in kg) | Bosch et al. (2017), ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019) |
| Resource management | Daily concentration of NOₓ in the air (g/m³) | ITU (2014), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
Table 1. (Continuation)

| DIMENSION                | CATEGORY / ATTRIBUTES | INDICATOR (units)                              | SOURCE                                                                 |
|--------------------------|-----------------------|-----------------------------------------------|----------------------------------------------------------------------|
| Resource management      |                       | Emissions of NO\(_x\) (%) in tons             | ITU (2014), Petrova-Antonova & Ilieva (2018)                         |
|                          |                       | Annual household waste per inhabitant (in kg) | Bosch \textit{et al.} (2017), ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019) |
| Environment              |                       | Daily concentration of NO\(_x\) in the air (g/m\(^3\)) | ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019) |
|                          |                       | Daily concentration of particulate matter, PM in the air (g/m\(^3\)) | ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019) |
|                          |                       | Daily concentration of CO\(_2\) in the air (g/m\(^3\)) | Bosch, \textit{et al.} (2017), ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019) |
|                          |                       | Waste generation per inhabitant (in kg)       | Bosch \textit{et al.} (2017), ITU (2014), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018) |
| Sustainable urban planning|                       | Green space per inhabitant (in m\(^2\))       | Bosch \textit{et al.} (2017), ITU (2014), Petrova-Antonova & Ilieva (2018) |
| Smart Buildings          |                       | Number of buildings certified Energy Leadership and Environmental Design, LEED (number) | Ahvenniemi \textit{et al.} (2017), Bosch \textit{et al.} (2017), ITU (2014) |
| Online services          |                       | Information Exchange Channels (Likert 1-5)    | Bosch \textit{et al.} (2017), Petrova-Antonova & Ilieva (2018)       |
|                          |                       | Citizen participation (Likert 1-5)             | Alvarado López (2017), Bosch \textit{et al.} (2017), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
| Government               |                       | Transparency of The Administration and the Government (Likert 1-5) | Bosch \textit{et al.} (2017), Petrova-Antonova & Ilieva (2018) |
|                          |                       | Open data (Likert 1-5)                        | Alvarado López (2017), ITU (2014)                                   |
|                          |                       | Number of databases (%)                       | Alvarado López (2017), Bosch \textit{et al.} (2017)                 |
|                          |                       | Wi-Fi coverage (per km\(^2\))                | Alvarado López (2017), Bosch \textit{et al.} (2017)                 |
|                          |                       | Diversity of monitoring sensors (Likert 1-5)  | ITU (2014)                                                            |

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Table 1. (Continuation)

| DIMENSION     | CATEGORY/ATTRIBUTES          | INDICATOR (units)                          | SOURCE                                                                 |
|---------------|------------------------------|--------------------------------------------|------------------------------------------------------------------------|
| Health        | Life expectancy (years)      | Bosch et al. (2017), Petrova-Antonova & Ilieva (2018) |
|               | Births per year (number)     | Bosch et al. (2017), Petrova-Antonova & Ilieva (2018) |
|               | Online integration of medical services (Likert 1-5) | Alvarado López (2017), Petrova-Antonova & Ilieva (2018) |
| Quality of Life| Traffic accidents per year (number) | Bosch et al. (2017), Petrova-Antonova & Ilieva (2018) |
|               | Crime rate (%)               | Bosch et al. (2017), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018) |
| Security      | Legislate cybersecurity (Likert 1-5) | Alvarado López (2017), Bosch et al. (2017), ITU (2014) |
|               | Data Privacy (Likert)        | Alvarado López (2017), Bosch et al. (2017) |
|               | Number of public schools (number) | Alvarado López (2017), Bosch et al. (2017), Monfaredzadeh & Berardi (2015), Petrova-Antonova & Ilieva (2018) |
|               | Number of universities (number) | Alvarado López (2017), Bosch et al. (2017), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018) |
|               | Research staff (%)           | Alvarado López (2017), Ahvenniemi et al. (2017), Bosch et al. (2017), Monfaredzadeh & Berardi (2015), Mori Memorial Foundation (2019), Petrova-Antonova & Ilieva (2018) |
| Integration   | Internet-connected homes (%) | Bosch et al. (2017), Petrova-Antonova & Ilieva (2018) |

Source: Own elaboration from Correia Carballo, 2017.

4. Results

There are multiple indices that position Smart Cities in a ranking. Each classification varies in terms of the methodology and indicators used, so it is difficult to find cities in the same position in different indices. The data presented in Table 2 correspond to the top five cities in 2020. The classifications considered are: IESE Cities in Motion Index (IESE Business School, 2020), The Global Financial Centers Index
(Financial Centre Futures, 2020), Global Power City Index (Mori Memorial Foundation, 2020) and Smart City Index (The IMD World Competitiveness Center, 2020).

Table 2. Ranking of Smart Cities in the World

| RANKING | IESE INDEX | THE GLOBAL FINANCIAL | GLOBAL POWER CITY IN. | SMART CITY INDEX |
|---------|------------|----------------------|-----------------------|------------------|
| 1       | London, United Kingdom | New York, USA | London, United Kingdom | Singapore, Singapore |
| 2       | New York, USA | London, United Kingdom | New York, USA | Helsinki, Finland |
| 3       | Paris, France | Shanghai, China | Tokyo, Japan | Zurich, Switzerland |
| 4       | Tokyo, Japan | Tokyo, Japan | Paris, France | Auckland, N. Zealand |
| 5       | Reykjavik, Iceland | Hong Kong, China | Singapore, Singapore | Oslo, Norway |

Source: Own elaboration from IESE Business School, 2020, p. 53).

Being a varied ranking for each of the indices shown in Table 2, the London and New York national team has been considered because they are repeated in three different rankings. Besides, Singapore has been chosen as the epicenter of origin of the Smart Cities (Alvarado López, 2017). Finally, it is a study that compares the results of the chosen cities and is detailed below.

4.1. Cases

4.1.1. Singapore

Population: 3,547,809 inhabitants  Surface: 692 km²

Singapore has established itself as one of the largest cities taken as a reference in the field of Smart Cities. Its high population density of 7,712 inhabitants per km² has led the Local Administration to take innovative solutions that ensure quality of life and facilitate it to all citizens. In response to the problem, since 2014 the Government has developed a project called Smart Nation, which aims as PM Lee, the country’s prime minister, said, to “create possibilities for ourselves beyond what we imagine possible” (Smart Nation, 2014). Among the measures present in the ambitious plan cited are the following.

In Smart Government it has opted to digitize most of the services it offers to the citizen. They highlight platforms such as CODEX, ready for the Government to
offer better faster and more cost-effective digital services; PayNow and NETS, both designated to facilitate electronic payment; NDI, which consists of a national digital identity document for digital transactions with the government and private companies; SNSP, which aims to provide wireless sensors in the city to collect concrete information and improve urban services.

While one of the key aspects for Singapore is the Smart Quality of Life of citizens such as the Smart Elderly Alert System server responsible for caring for the elderly by providing sensors in their homes. Regarding the field of health highlights the existence of the HealthHub application in which digital medical assistance is available. It also highlights the promotion of physical activity with the Healthy 365 platform.

Regarding Smart Mobility, the public transport service ordered on demand through the Beeline application stands out; and the Data Transport Data Land platform capable of showing the availability of taxis and car parks, traffic conditions and waiting time of the arrival of the bus or metro.

In Smart Environment, the boost to solar energy through photovoltaic panels arranged in 5,500 blocks of public housing and with capacity to generate 350 MWp of solar energy highlights. Regarding waste management, a system consisting of the use of underground pipes that collect recycled household waste stands out.

Figure 3 shows Singapore’s different positioning for each of the meters according to Mori Memorial Foundation (2020) and highlighting the functions of Smart Mobility, Economics and Cultural Relations.

Figure 3. Singapore profile in each of the areas

**Singapour**

- Economy
- Mobility
- Environment
- R+D
- Cultural Interaction
- Quality of Life

*Source: Own elaboration from data obtained from Mori Memorial Foundation, 2020.*
4.1.2. London

Population: 8,908,081 inhabitants  Surface: 1,572 km²

The indices presented in Table 4.1 of IESE Cities in Motion and Global Power City Index position London on the podium of honor as the best Smart City of 2020. The main reason that justifies its position in rankings is the need for transformation and evolution due to increases in its coming population, such as the million people expected between 2011 and 2021 (London City Hall, 2013) or the average age of the population in 33 years making the city more cosmopolitan and dynamic (IE Business School, 2019).

London’s strategy for achieving the necessary transformation and evolution revolves around the 2013 project called Smart London Plan. Actualized in 2016, the project allows Londoners to participate in the choice and proposition of ideas (Smart London, 2018). Projects of the respective annotated plan are detailed below.

The Smart Government is backed by the Talk London platform, based on the Crowdfund London server, where citizens review, debate and participate in surveys and events. It also highlights the creation of the London Datastore, a free and open portal used by more than 50,000 citizens, companies and researchers among others, and which has up to 700 organized data sets of employment, economy or transport. In addition, the London consistory will install 5G devices every 200 meters through the streets allowing an effective connection of the servers (Bleda, Jara, Gómez Skarmeta, Maestre, Pellicer & Santa, 2013).

Among the initiatives developed is the innovation laboratory presented in the Harrow neighborhood in collaboration with techUK, part of the field of R&D investment in Smart Economy. It also highlights the creation of the London Office of Technology and Innovation, LOTI, in which the City Council supports collaboration and participation in the exchange of technology between public offices, as well as digital collaboration, imported from the formula presented in Singapore with the CentEx platform.

With regard to Smart Mobility, the project to move towards digitization highlights, what has allowed London to be the first city to introduce contactless card payment for transport for London, TFL, which includes the metro or bus and prevents cash payment (Smart London, 2018). This idea is envisaged in the plan that TFL intends to implement so that 100% of the services are digitized by 2030 (Project 2030 TFL, 2020). In turn, the City mapper application stands out, responsible for selecting the best transport route, as well as electronic payment. However, the largest project envisaged by the consistory is the Crossrail Project which consists of the design of a railway line that links the east and west of the city on a 21 km stretch and where each station on the line contains: 50 km of wiring, 200 CCTV cameras, 66 information screens, 750 speakers and 50 help points (IESE Business School, 2020).

Environmental initiatives include the control of pollution in the city by sensors installed in the streetlights, which to obtain more accurate information of the state
of the air. Although, from the consistory they retain to achieve zero CO$_2$ emissions by 2050, unlike other cities such as Copenhagen fixed in 2025. The plan envisages an area of the center in which to restrict traffic and that will expand to other areas by 2025 (TFL, 2019), reduce household waste by 50% by 2030, encourage the use of 100% renewable energy in public sector companies and deprive or reuse heat obtained in waste management for underground wells and incorporate (Bleda et al., 2013).

Figure 4 shows the different London positions for each of the meters according to Mori Memorial Foundation (2020), highlighting most areas with relevance in Economics, Mobility, R&D and Cultural Relations.

Figure 4. London profile in each of the areas

4.1.3. New York

Population: 8,398,748 inhabitants Surface: 1,214 km$^2$

The most populous city in North America and the highest population density per km$^2$ features a Smart City plan unveiled in 2015 called One New York: The Plan for a Strong and Just City. The information below has been obtained from the New York City Council portal in the section for the One New York plan (2015).

One of the proposals of the consistory is to maintain contact with the citizen so that the citizen can obtain information about the main services and activities in the city or warn of existing incidents. The app and web portal are known as 311 New York City and has 175 languages available. This tool is part of the strategy in the development of Smart Governance together with the LinkNYC platform that allows...
connection to a Wi-Fi network, the loading of the mobile device, access to services and maps of the city and the development of emergency calls to the 911 (IESE Business School, 2020).

The New York police service has been a pioneer in the use of DAS server whose objective is to monitor the city, that is, to track or obtain information about surveillance targets. This system can collect data such as: 2 billion vehicle license plates, 54 million 911 calls or 15 million complaints; for this purpose, it presents up to 18,000 CCTV cameras distributed.

In the area of Smart Mobility, responsible transport management is intended. To this end, the Midtown in Motion project has been developed, which aims, on the one hand, to manage traffic in order to avoid congestion of vehicles on public roads and, on the other hand, to prioritize collective transport such as the bus. First, the system incorporates microwave sensors, video cameras and EZPass readers that collect traffic information. Secondly, a pioneering system is served to prioritize the 5,700 buses in the city that carry 2.5 million users. This system has developed those known as Select Bus Service being express services that are subject to priority in traffic.

However, the city’s greatest interest remains in the Area of Smart Environment. New York spends $600 million a year to give electricity to its public buildings and city streets. Thus, the objective is to reduce the costs and effects that can be located in the environment by it is use; therefore, the consistory has promoted private initiatives based on the use of LED lights, such as that carried out on 86 fire stations with which CO₂ emissions were reduced by 520 tons. In waste management, the goal for 2030 set is to achieve zero emissions in old landfills and in all schools in the city (IE Business School, 2020), for this we want to start reducing the waste generated and is that in New York more than 20,000 tons of daily garbage is collected causing the constant displacement of trucks that emit pollutants to the atmosphere; one way to reduce the movements of collection vehicles, as well as the daily treatment of garbage, is by using smart bins known as BigBelly, which compact waste and alert you when it is full. Finally, water management goes through a streamlined consumption of it, and is that 3 million m³ of drinking water is distributed daily, which has led to the installation of a novel automated reading meter which warns of possible water leaks, as well as eliminates manual readings of the water meter by significantly reducing the bills of New Yorkers.

For its part, in Smart Economy, the great investment of the consistory in innovation projects highlights. The activity is developed by the New York Economic Development Corporation, an economic promotion agency in which relevant projects such as LinkNYC already mentioned have been presented. The growing funding of $13,884 million in startups in 2018 versus 2.579 million in 2008 (Fernández de Rojas, 2019) highlights too.

Figure 5 shows the different New York positions for each of the meters according to mori Memorial Foundation (2020) and highlighting the functions of Smart Mobility, Economics and R&D.
Figure 5. New York profile in each of the areas

New York

Source: Own elaboration based on data obtained from Mori Memorial Foundation, 2020).

4.2. Case study

The objective in this section is to show a comparison of the sample of each category of the study by its result in the report for each city.

Table 3 corresponds to the Institute for Urban Strategies (Mori Memorial Foundation, 2020) to commission or rate cities for each of the areas with a maximum of 520 and adding the total of 2,600 points.

Table 3. Data used for the sample

| CITY    | ECONOMY | R & D  | CULTURAL INTERACTION | QUALITY OF LIFE | ENVIRONMENT | MOBILITY |
|---------|---------|--------|----------------------|-----------------|-------------|----------|
| Singapore | 272,5   | 99,8   | 201,7                | 308,4           | 169,3       | 210,4    |
| London   | 328     | 186,8  | 380,5                | 349,1           | 168,1       | 248,5    |
| New York | 362,8   | 212,1  | 253                  | 308,6           | 154,5       | 223,8    |

Source: Own elaboration.

The results are shown below in Table 4. To do this, they have analyzed the categories (Economy, R&D...) for each city.
Table 4. Non-paramedical test results in SPSS

| City       | Category          | N  | Average | Range |
|------------|-------------------|----|---------|-------|
| Singapore  | Economy           | 1  | 5       |       |
|            | R & D             | 1  | 1       |       |
|            | Cultural Interactions | 1 | 3   |       |
|            | Quality of Life   | 1  | 6       |       |
|            | Environment       | 1  | 2       |       |
|            | Mobility          | 1  | 4       |       |
|            | Total             | 6  |         |       |
| London     | Economy           | 1  | 4       |       |
|            | R & D             | 1  | 2       |       |
|            | Cultural Interaction | 1 | 6   |       |
|            | Quality of Life   | 1  | 5       |       |
|            | Environment       | 1  | 1       |       |
|            | Mobility          | 1  | 3       |       |
|            | Total             | 6  |         |       |
| New York   | Economy           | 1  | 6       |       |
|            | R & D             | 1  | 2       |       |
|            | Cultural Interaction | 1 | 4   |       |
|            | Quality of Life   | 1  | 5       |       |
|            | Environment       | 1  | 1       |       |
|            | Mobility          | 1  | 3       |       |
|            | Total             | 6  |         |       |

**KRUSKAL TEST STATISTICS - WALLIS**

| City       | Kruskal H - Wallis | Degrees of Freedom | Sig.   |
|------------|--------------------|--------------------|--------|
| Singapore  |                    |                    |        |
| London     | 5                  | 5                  | 0,416  |
| New York   |                    |                    |        |

*Source: Own elaboration.*
In descriptive statistics, the maximum and minimum values obtained by each city by a category, as well as the median of all of them by region, are of interest. In the case of Singapore, its maximum is in Quality of Life and its minimum in R&D. About London, it stands out above Cultural Interaction and for the low environment. Finally, New York collects its highest and lowest score in Economics and Environment respectively. For its part, the median orients that the city that presents a better position in the rankings is London, followed by New York and Singapore. This trend coincides with the list of cities in the Mori Memorial Foundation ranking (2020) presented in Table 2.

The Kruskal – Wallis Test shows that 6 categories are analyzed for each of the cities. The highest average range in Singapore is for Quality of Life and the lowest for R&D. In London Cultural Interaction stands out, with higher rank, and Environment, with lower rank. Meanwhile, in New York the highest rank is in Economics and the lowest in the Environment.

The Kruskal – Wallis Test Statistics results show the value of the H statistic being 5, as well as the degrees of freedom. In addition, the asymptotic significance is 0.416 and, therefore greater than 0.05. This fact leads to accepting the null hypothesis raised with a significance of 5%.

Finally, it concludes with a representation of the score obtained for each city versus the categories (Figure 6).

Figure 6. Kruskal – Wallis test for independent samples, Cities vs. Categories

![Figure 6. Kruskal – Wallis test for independent samples, Cities vs. Categories](image)

Source: Own elaboration.

5. Sustainable Smart City model proposition

A Smart City, in line with the comments, is a constant update of the proposed city model, being one that facilitates and improves the quality of life of an entire
Application of ICTs in the development of Sustainable Smart Cities

thriving society by using tools such as ICT. This will provide answers to your needs and safeguard the planet for it is care and conservation, eventually giving rise to the Sustainable Smart City (United Nations, 2018). This way, there are two agents a Smart City serves that are, people and earth, through resources, such as ICTs.

There are six fundamental pillars of action: Economy, Government, Environment, Mobility, Smart Society and Quality of Life. Ideas that consolidate the Sustainable Smart City will then be provided on each pillar.

5.1. Smart Economy

There are two benchmarks for the Area of Economics, and they are: R&D investment and business creation.

R&D investment

An investment in R&D by the public and private sectors allows to retain knowledge, lead projects above other cities and ensure the advancement of society towards a future era.

The main objective is the presence of spaces dedicated to research and in which any citizen can contribute and share knowledge with the community. Those known as Fablab serve as an example. The implementation of the initiatives that have arisen can take place in neighborhoods dedicated to the testing of projects before being taken to the whole city and that have already emerged effects in cities such as Barcelona with the District 22 project in which the creation of 100,000 jobs and the increase of 25% of the population in the chosen Poble Nou district (Sh Barcelona, 2016) has been boosted since 2000.

Creating companies

For the reduction of the number of standing in the country and the increase in GDP, initiatives are of interest to help the creation of companies through platforms that facilitate the management of formalities. An example is the presence of a unique portal capable of managing different functionalities of entrepreneurship in a company such as the Madrid Emprende plan that in 2018 had the support of 3.4 million euros for entrepreneurs and that helped about 64,000 companies in the same year (Madrid Emprende, 2018).

5.2. Smart Government

Among the most important indicators are online services for citizens, open government and available infrastructure.
**Services provided online**

The provision of a CRM, Customer Relationship Management, makes it included in a single platform functions such as providing information on activities, air and water quality, communicating incidents on public roads and traffic or attending suggestions, proposals and surveys to citizens. An example is the 311 New York City applications, the Talk London platform, or Decide Madrid.

**Open government**

It aims to publish all public data to generate value with them and inform the citizen of the executive’s plans, thus involving him in the activities. It is proven that open data generates 1% more annual GDP compared to the closed government (Mayor & Molina, 2018). Many cities already have this tool highlighting the 1,798 data available from the Government of Singapore compared to the nearly 700 presents in London Datastore the 462 in Barcelona or the 452 in Madrid.

**Available infrastructures**

The resources available are the use of ICTs to develop initiatives to help generate mapping, thermal maps and vegetation indices of an entire city at high speed, in what is known as Mobile Mapping included in the Geographic Information System, GIS, through the use of cameras and sensors mounted on a vehicle equipment. The use of this technology helps to locate incidents in the city, as well as the concentration of heat in homes and other facilities among others. On the other hand, it highlights connectivity on public roads, as well as in public transport of an efficient and scalable network from fiber optics, microwaves, MPLS data carriers, Wi-Fi networks or the proportion of Ethernet in VPLS networks. The initiative is already present in cities such as New York where the LinkNYC service exists with 1,777 poles distributed through the 5 districts of the city.

### 5.3. Smart Environment

In the environment, action lies in measures that try to alleviate effects that damage the natural space such as climate change. In order to avoid major consequences in the environment, many cities have presented the ambitious goal of achieving zero CO₂ emissions such as Copenhagen set in 2025 or London by 2050, which are already working on proper management of water, energy, waste and air quality.

**Water management**

Proper water management is a controlled consumption that prevents large losses. In this way, and to control the water consumed, devices capable of measuring and monitoring multiple parameters and variables of interest to the user are presented. These devices work wirelessly through Sigfox networks and allow readings of water consumption, as well as gas or energy, and control quality (Arévalo Tapias, González...
González & Hernández Gutiérrez, 2019). About irrigation in parks and gardens of the city, an online management system can be used through which satellite images are provided that identify the type of vegetation and the state in which they are located.

**Energy management**

Boosting the use of renewable energy such as solar or wind should be the priority set by the consistory to reduce the carbon footprint left by conventional energies to date, so solar panels will be used in public housing and administration buildings as is already the case in Singapore and Copenhagen. On the other hand, regulations are established to restrict high-rise buildings, as well as to ensure sufficient separation between homes to allow natural light to arrive and the supply of solar energy in those with photovoltaic panels. In addition, LED lights will be available throughout the city’s street lighting, reducing annual consumption by 60%; and smart lights sensitive to the presence of people on the track will be used as a pilot program. Regarding the construction of buildings, those with the LEED certificate will be viable.

**Waste management**

Selective collection must be a reality throughout the city, so that all streets will have smart containers arranged by colors for recycling. These containers will have a system capable of detecting, through sensors communicated with a central post by Sigfox networks, when they are full, dumped or burned; in addition, smart bins such as those used in New York known as BigBelly will also be installed.

**Air quality**

Vehicles are the main precursors to the poor air quality that is breathed in a city, however, not all cars impact the same way. To do this, an emissions monitoring system is designed in all vehicles and machinery that connects with the Devices Bus CAN, Controller Area Network, in order to know and reduce the emissions of gases emitted by them (Martínez Requena, 2017). In addition, the promotion of programs that facilitate the use of low-emission vehicles, renewing the municipal fleet such as taxis and buses takes place. Apart of this, with a view to identify the most sensitive and therefore worst air quality areas at the moment, a system consisting of mobile devices, such as those arranged in municipal vehicles or rental bicycles, and fixed, present in public buildings, which use the Internet of Things to produce heat maps of the Environmental Quality Index (Escribano, Torres & Ventura, 2019) is presented.

5.4. Smart Mobility

Among the indicators best valued in a Smart City are the correct traffic management and the efficient infrastructure available.
Traffic management

The main problems generated by traffic on public roads are air and noise pollution, visual impact and increased waiting times for road traffic. In many cases, it is inevitable to crowd cars on the streets. However, in other cases, the problem can be overcome by using smart sensors that help prioritizing public transport, as the one used in New York from the mentioned Midtown in Motion project. Also, there are applications that show the availability of underground parking spaces and on the surface with wireless counting sensors in each of the squares such as the Data Transport Data Land application in Singapore. In addition to high occupancy lanes for vehicles with 2 or more occupants to promote shared trips, the initiative in Madrid with the Bus VAO lane is present. On the other hand, the limitation on the entry of vehicles into certain areas of the city is effective if accompanied by an improvement in public transport.

Available infrastructure

Among the infrastructures to be available by a city for traffic management is the presence of bike lanes throughout the city, including the center, as presented by Copenhagen city that has 650,000 bicycles compared to 125,000 vehicles, in addition to presenting an extensive network of 340 km that is expected to extend with 300 km more (IE Business School, 2020). Meanwhile, digital resources include the use of mobile apps that help promote different alternative transport routes to the private vehicle such as the mentioned Citymapper. On the other hand, mention the order transport system already presented by Singapore, by which the user can design his own route thus sharing it with other travelers; this system has recently been established in EMT Madrid with the provision of the first line on demand in a pilot project for incidents by COVID-19.

5.5. Smart Society

Education proves to be essential today as it guarantees the prosperity and growth of a city in future times, so this is the main dimension on which greater support will be turned.

Education

In the current digital age it is of interest to present projects that encourage the use of electronic resources in classrooms such as the mSchools project in Barcelona; the interconnection of private and public schools for the transfer of files and the transmission of information between the school and legal guardians, through platforms such as Parents Gateway in Singapore. The construction of children’s schools is promoted as is already the case in Tokyo where, the National Strategic Special Zone plan has been presented, which involves this activity together with the promotion of equality between parents to raise the child. On the other hand, education must
not only be a protagonist in schools and institutes, but also, it can be exercised in spaces assigned by the city council, as squares, for the promotion of communities in which activities are promoted, exhibitions of local products or the setting of urban orchards as is the case in the Japanese city of Fujisawa (Fujisawa SST Council, 2018) or in Madrid with the so-called Civic Squares.

5.6. Smart Quality of Life

**Health care**

If a city’s health skills are served, they are focused on the care of the elderly and dependents, as well as programs that promote physical activity. Projects such as the installation of sensors in dependent, disabled and 3rd age households can help detect any irregularities and alert the city’s emergency service; Meanwhile, health programs to prevent sedentary life in citizens can be effective, such as the Singapore-willing one called Healthy. Bike-shared walking routes and boosting healthy food by removing foods with large amounts of sugars and fats easily found in vending machines are also touted.

**Security**

Correct security for the citizen guarantees a thriving city and quality of life. There are many existing emergency services that work to ensure that anyone is resident in the city, is safe in it, so to facilitate the connection between the different security forces there must be an LTE broadband network, Long Term Evolution, which unifies communications of the different services and facilitates interconnection with all the elements available in a city such as cameras or sensors. The proposal is a reality with emergency numbers such as 112 in Europe, 911 in America or 119 in certain Countries in Asia. In turn, video surveillance cameras on the streets have to be renewed by high-precision and high-speed cameras with ANPR detection programs, Automatic Number-Plate Recognition, with zoom lens capable of recognizing license plates or performing electronic toll collection; as well as having sensors such as those presented in New York through the DAS system already mentioned.

Conclusions

A Smart City is characterized using ICTs to facilitate and improve the quality of life of the inhabitants who reside it. There are six areas of action in a Smart City being: Economy, Government, Society, Quality of Life, Mobility and Environment. The concept of Sustainability is added, which favors cities that seek a sustainable balance between the economic, social and environmental spheres.
To initiate the transformation to Sustainable Smart City requires the development of a City Plan agreed with the different political formations and municipalities, support of the legal framework for relations between the local council and companies, public financing with private participation, and the development of sustainable business models.

Finally, it is worth noting the role that Smart Cities can play in extraordinary emergencies such as those carried out by weather conditions or the recent pandemic caused by COVID-19, which has come to strengthen digital channels for telework, health care or education. Today, world characterized by uncertainty and the need to be flexible to adapt to changes, the aspects analyzed for the development of a Sustainable Smart City need to be constantly defined and revised. The pandemic that arrived in 2020 has highlighted the importance of investment in R&D, smart governance and the management aspects of water, energy, and waste and air quality. For this reason, there has been a process of rethinking in areas such as mobility, with the issue of Smart Mobility being of particular importance with the power of bicycle use. Added to that is the need to develop the idea of Smart Society, which must look for new educational approaches under online platforms. Another aspect that is fundamental to the field of smart economy is the redefinition of business, that is, the need to modify the business models of companies to adapt them to new needs and to create new companies that serve them. In addition to, to enhance the Smart Government with the management of formalities, collections and any other activity of the Administration via telematics. Finally, Sustainable Smart Cities, which focus some of their attention on Smart Quality of Life, can provide the necessary health care and safety and be prepared to respond quickly and appropriately to any health, environmental or social problems that may arise in the future.

Possible lines of research that may serve to continue this project are:

- Analyze in depth and independently each of the areas presented.
- Present an economic study of the expenditure carried out by initiatives that promote the Smart City. This would allow us to know which territories are eligible for one of the above-mentioned initiatives based on their cost.
- Develop a comparison between those Smart Cities disaggregated by number of inhabitants (high, medium and low population) population with high, medium and low population; this would look at what society is demands are in different regions.
- Develop a City Plan for a particular region where the problems of society are exposed, and solutions are proposed.

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The authors declare that they have no conflict of interest in relation to the research, authorship or publication of this work.
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