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Smart and sustainable city: Singapore, success case

Ciudad inteligente y sostenible: Singapore, caso de éxito

Julián A. Correa-G. [1], Andrés Escobar-Díaz [2], Harold Vacca-González [3]

Abstract: The following paper focuses on the qualitative description of the nation city of Singapore and its quantitative evaluation, which are part of an exploratory research for the ORCA and *SciBas* research group of the Francisco José de Caldas District University. Therefore, during the first semester of 2018, a conceptual review was made on the subject, proposing an action methodology whose snuyources are selected with the category of *smart city* in the context of *sustainability*.

The search for information, both national and international, was focused on the databases: IEEE Xplore, ScienceDirect, Springer Link, among others; and in the search for the evaluation model.

Keywords: Automatic learning, Cloud computing, E-Government, Internet of things, Machine to machine communication, Smart City.

Resumen: El siguiente trabajo se centra en la descripción cualitativa de la ciudad nación de Singapur y su evaluación cuantitativa, que hacen parte de una investigación exploratoria para el

[1] Electronic Technologist, Universidad Distrital Francisco José de Caldas, Colombia. jacorreag@correo.udistrital.edu.co https://orcid.org/0000-0002-6074-7283
[2] Electronic engineer, Universidad Distrital Francisco José de Caldas, Colombia. Master's degree in engineering, Master's degree in administration, Los Andes University, Colombia. Professor at the Universidad Distrital Francisco Jose de Caldas, Colombia. aescobard@udistrital.edu.co https://orcid.org/0000-0003-0527-8776
[3] BSc. in Mathematics, Universidad Distrital Francisco José de Caldas, Colombia. MSc. in Applied Mathematics, EAFIT University, Colombia. Professor at Universidad Distrital Francisco José de Caldas, Colombia. hvacca@udistrital.edu.co https://orcid.org/0000-0001-7017-0070

grupo de investigación ORCA y SciBas de la Universidad Distrital Francisco José de Caldas. Por lo tanto, durante el primer semestre de 2018, se realizó una revisión conceptual sobre el tema, proponiendo una metodología de acción cuyas fuentes son seleccionadas con la categoría de ciudad inteligente en el contexto de la sostenibilidad.

La búsqueda de información, tanto nacional como internacional, se centró en las bases de datos: IEEE Xplore, ScienceDirect, Springer Link, entre otras; y en la búsqueda del modelo de evaluación.

Palabras clave: Aprendizaje automático, Computación en la nube, Gobierno electrónico, Internet de las cosas, Comunicación máquina a máquina, Ciudad inteligente.

1. Introduction

A smart city is an urban environment aimed to improve the life quality of the citizens that inhabit it, using technology to achieve social and economic development, and where multiple sectors systematically cooperate to achieve sustainable results [1],[2]. This article is focused on the qualitative description of the nation-city of Singapore and is part of an investigation to conceptualize and understand the smart cities topic, as well as the evaluation of it.

In accordance with the above, Singapore in 2014 established a plan aimed to transform the existing nation-city in an advanced place, considering the citizen as the main axis of all changes to be made. The smart nation plan, see Figure 1, was focused on the management and proper handling of urban growth and energy sustainability. The focus of the vision of Singapore was developed in areas such as transport, security, energy, construction, education, health, among others [3], [4].

This is why, thanks to the fact that this city has found the means to take advantage of the challenges and turn them into economic opportunities due to the intelligent use of information and

communication technologies (ICT), the experience has been successfully replicated by implementing some of these solutions in other cities, allowing Singapore to progressively become a worldwide level smart city [5].

Consequently, the article focus is aimed at showing the *nation-city* of Singapore as a *success case* because of its efforts in the implementation of ideas and projects that have allowed it to stand out as one of the smart cities established in the world. The categories that Singapore has focused on in its smart nation plan are the following:

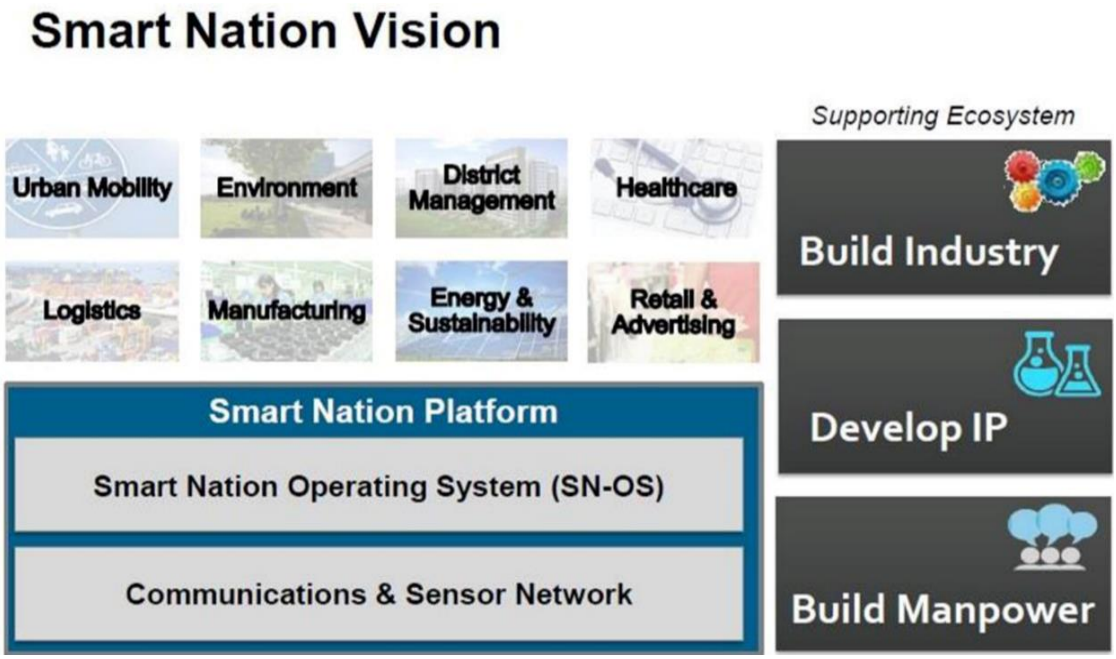

Figure 1. Singapore's smart nation vision, [3].

- ***Smart Mobility***

Systematically understanding the city, coordinating efficiently to facilitate the live of the people and their daily commuting

- ***Energy efficiency***

  Correct and properly use of energy as one of the fundamental aspects for measuring sustainability in the city.

- ***Government and research policies***

  Facilitating the city administration by simplifying the procedures of citizens and the proper management of government entities, allowing faster solutions to everyday and recurrent problems that occur in urban environments.

- ***ICT (Information and Communication Technologies)***

  Controlling the data flow for further processing and analysis, managing the information to ensure the knowing everything that happens in the city reality at any time of the day. Here are related aspects such as the Internet of Things (IoT) and big data (Big Data), necessary tools that offer connectivity to all the systems that are managed in Singapore.

2. Methodology

The smart city concept has been strongly established in the last decade of this century because it has radically changed the way people live in modern cities. That is why, in this period, through a comprehensive bibliographic review, the article aims to illustrate, understand, and conceptualize why Singapore is considered a success case and a real example of implementation of this type of city.

Given the current status of the subject, and at the same time poor academic literature, the methodology is covered in a *documentary research modality* [6] from which a contextualized

conceptual review (heuristic) on *smart cities* is obtained from the establishment of five categories with their respective subcategories: ***Smart Mobility*** *(Mobility integration, Sustainable public transport service, Electric cars, Autonomous vehicles, Transport and citizens)*; ***Energy efficiency*** *(Renewable Energy, Natural Resources Management and measurement of environmental parameters);* ***Government and Innovation Policies*** *(E-Government, Directive Intervention, Facilitating Intervention);* ***Smart Health*** *(Telehealth and solutions provided by ICT)****;*** and the use of **ICT** for the *generation, transmission and information processing (Machine learning, Internet of Things (IoT), sensor networks, Big Data)* that occurs daily in Singapore. Afterwards, the stage of interpretation (hermeneutics) of the sources on the Instrumentation for *Smart Cities* is carried out. Figure 2 shows the methodological model followed, validated by the *Orca* and *SciBas* research groups.

Finally, after consulting information in different databases such as: IEEE Xplore, ScienceDirect, Springer Link -among others-, they are classified and interpreted to evaluate the city of Singapore as a success case using the GMSDIV model *(Governance, Mobility, Sustainability, Economic Development, Intellectual Capital, Life Quality)* given in [7]. As a result of the research, in addition, an *Integrated and Complementary Systems Network (ICSN)* is obtained, showing the existing relationships between the different systems and elements that Singapore has incorporated to become a smart city. From this point of view, it is the integration and complement of systems what determines success as a *Smart City* case.

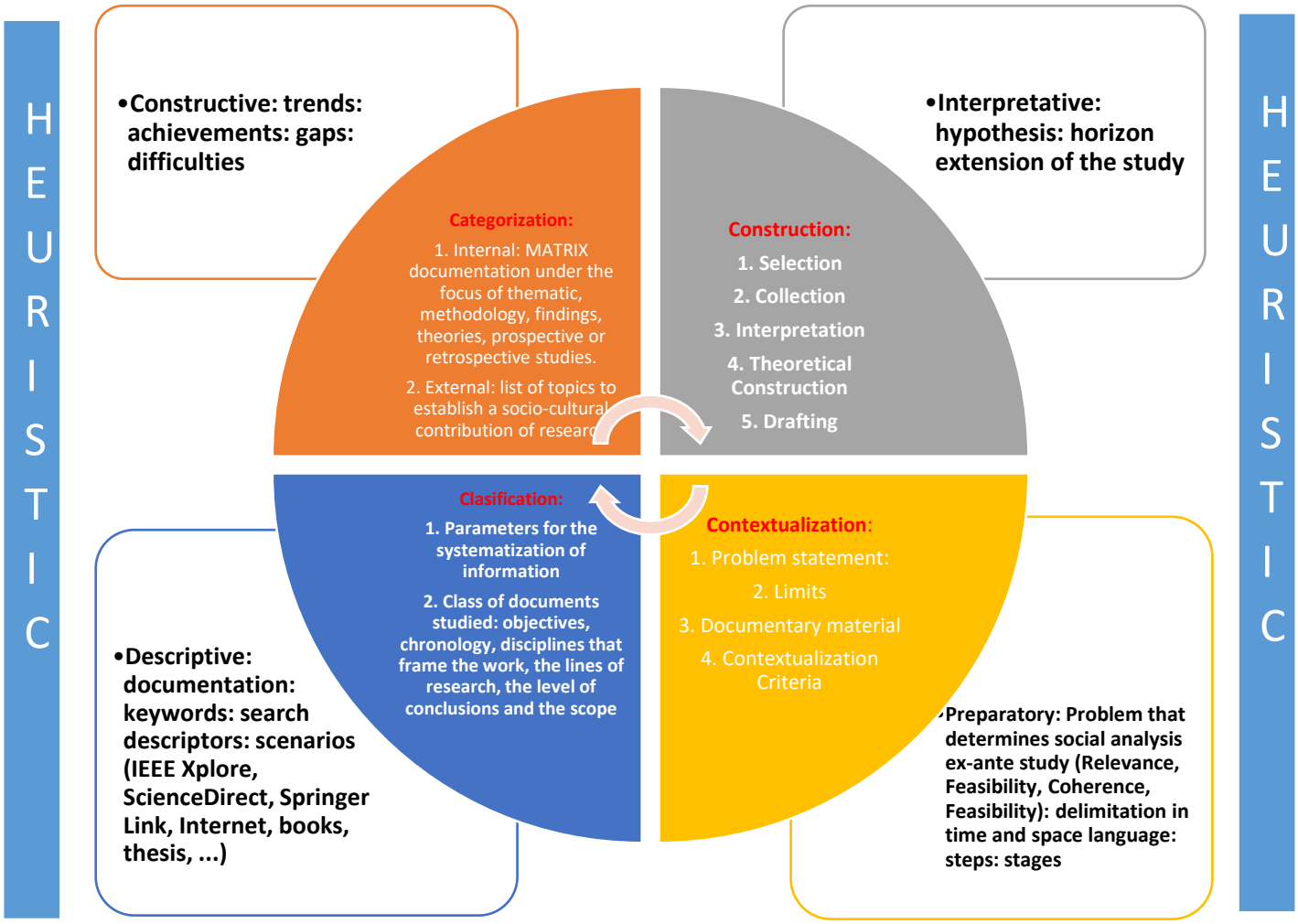

Figure 2. Scheme that describes the documentary research methodology followed for contextualized conceptual revision on *smart cities.*

Source: own.

3. Results

Singapore is a State City in which the government has sought to improve the city through the implementation of strategic plans; in 2014, for example, they adopted a nation plan that included services in different areas such as mobility, health, and safety. In a first step, Figure 3 shows the level of increase in the population of Singapore from 1960 to 2017. This high rate of population

increase meant taking relevant actions to allow citizens to access an adequate life quality, making Singapore a city that adapted to both environmental, social, economic, and political changes.

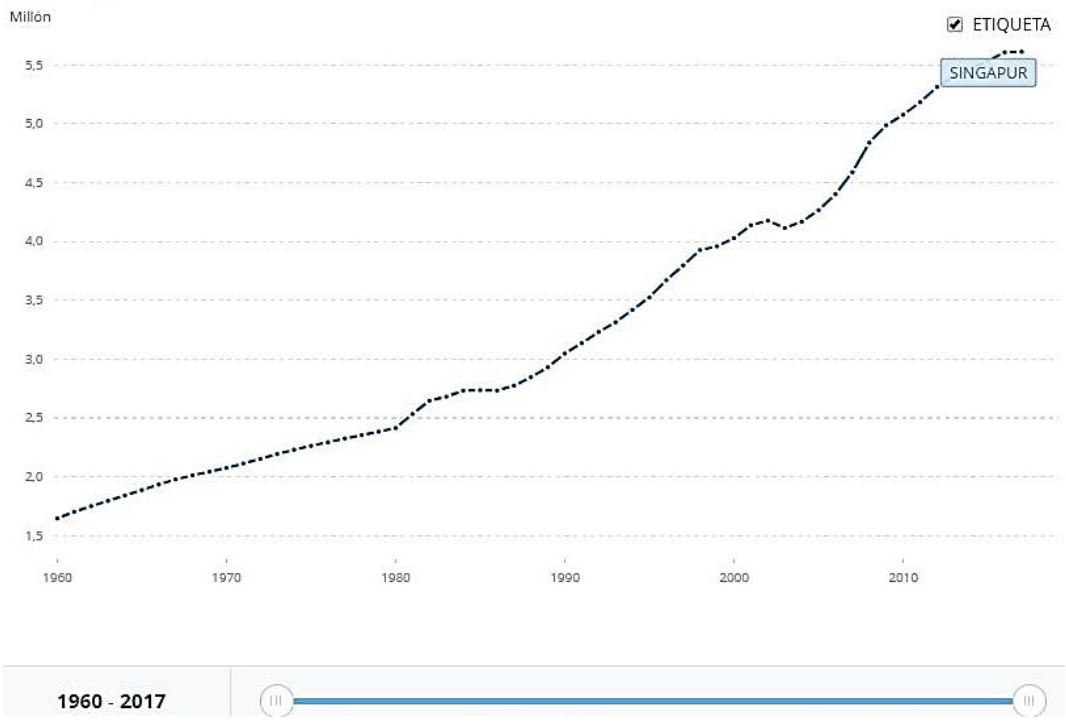

Figure 3. Increase in the population of Singapore from 1960 to 2017 [8]

Similarly, the rate per capita, as shown in Figure 4, showed a significant increase from 1985 to 1997 due to innovation policies that the city incorporated; measures that have made it possible to show over the years how the proper planning of projects executed with public-private partnerships allowed improving the economy of the city.

3.1. *Smart Mobility*

The city is characterized by an intelligent transport system (ITS), developed since 2006, which establishes a massive rapid transit system (MRT) to provide national interconnectivity [9]. They have a monitoring system (one monitoring) to access transit information that is collected by a network of cameras installed in the streets and by taxis with GPS. Likewise, with the application

developed by the LTA[4] they monitor incidents on the roads and with an smart electronic device *(Your speed sign)* alert drivers of the speed limit [3],[10],[11]. Electronic payment to access the transport system generates benefits that are evident in reducing the time to access the different transport means, ensuring comfort to users, [12].

- **Mobility integration**

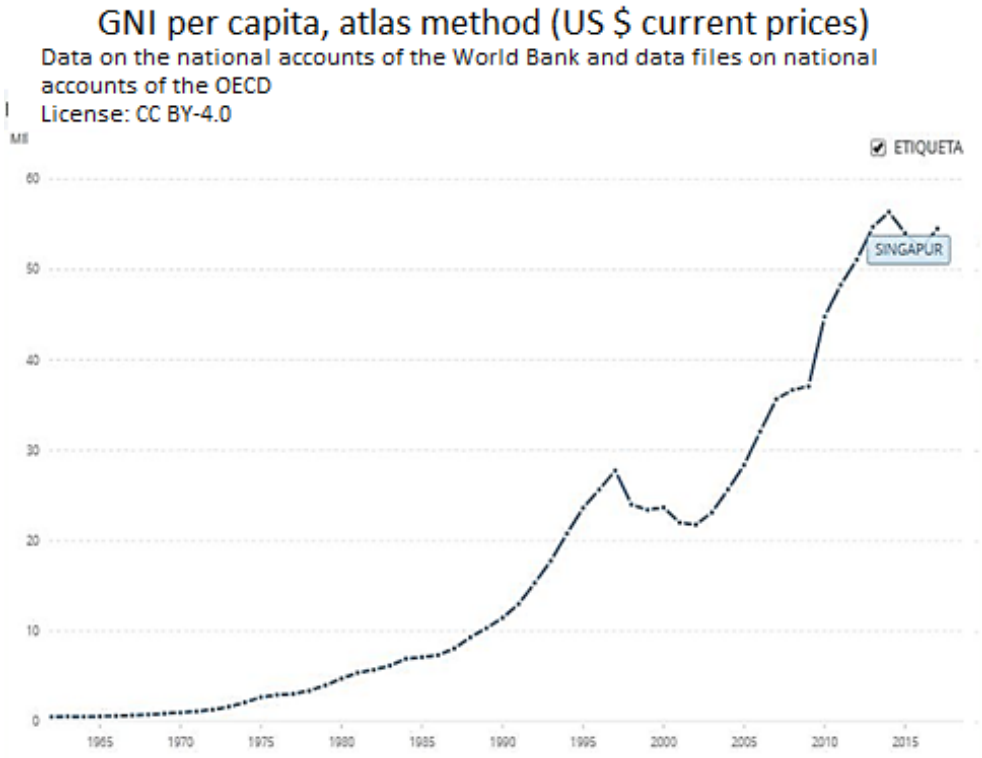

Figure 4. Singapore city per capita index from 1960 to 2017 [13].

One option to integrate different transport means is through shared service that allows different users to use the same vehicle to move to different parts of the city. Mobility concepts such as MaaS[5] (Mobility as a service) help to buy mobility services which are packages based on the needs of

[4] Land transport authority by its acronym in English (LTA)
[5] MaaS: Mobility as a service

consumers instead of buying them on transport means. Another function offered by this service is the ticket and payment integration through the use of a smart card that can access different transport means, making charge from the use of each service used. The EZ-link[6] card is used in Singapore with high acceptance by users because it eliminated payment barriers between operators in the transit network [14],[15],[16].

- **Sustainable public transport service**

The construction of a city must take into account the social and environmental perspective focused on sustainability; looking for this, public transport must provide the tools to achieve a dynamic and transformative development for urban regions [17]. Finding new innovative forms of transport is part and differentiates an smart city from a traditional city [18],[19]. It is important to emphasize that socio-emotional factors have a significant influence on the people decisions to access or use some transport means and, taking these factors into account, it is necessary to understand and consider the different transport means that facilitate the users flow [20],[21].

- **Electric vehicles (EV)**

A study in Singapore indicates that the widespread use of this transport means reduces the air pollution levels, compared to traditional combustion vehicles; in turn, EVs offer greater energy efficiency and lower energy costs [22],[23].

Electric car charging stations are controlled and monitored by an electric network management system to establish how much is available for charging the electric car, avoiding congestion at the stations and facilitating the collection to the vehicle owner [24],[25],[26].

[6] Singapore transportation pass

- **Autonomous Vehicles**

Autonomous vehicles will be part of the cities in the near future, so knowing the benefits they offer and the way they can adapt to the existing mobility ecosystem is an obligatory study to obtain the best results in its implementation. In Singapore, through the *SimMobility* application (integrated model of supply and demand based on agents) the shared autonomous vehicle could anticipate the demand in the mobility service to reduce waiting times and ensure a balance between the vehicles required and vehicles available in each area [27].

- **Transport and citizens**

Adapting the transport means to the needs of all citizens is a task that must be carried out by government entities and the sectors involved, if are wanted the best services to be provided to the city population. In [28] is presented, for example, the study of the activity patterns performed by people over 50 (trend age) to know in detail the use of the time in order to optimize the performance of activities and thus offer the transportation methods that this age level of society requires.

- **3.2. *Energy efficiency***

On energy efficiency subject, Singapore implemented an power grid with smart meters to know the electricity consumption and the electricity contribution to buildings by vehicles (V2I)[7] [24], to subsequently monitor and achieve cost reduction. The electricity levels of consumption can be affected if this electric flow is not adequately controlled and that is why customers are indispensable to make this supply control effective in Singapore buildings. [29],[30], [31].

[7] V2I: Vehicle to infrastructure. One of the applications of this technology is to supply electricity in periods of high demand to buildings by electric vehicles through a smart grid.

Defining the appropriate norms or laws that regulate these micro-grids is important to standardize and facilitate their implementation, [32].

Figure 5 shows an smart grid system where all the necessary infrastructure is established to obtain improvements in energy efficiency subject where buildings, vehicles and renewable energy systems are integrated to know the state of energy consumption supported mainly by smart meters equipped with communication capabilities that provide enough information for city officials to make decisions regarding continuous work with citizens to reduce the energy waste that promotes a sustainable urban environment.

It was possible to improve, then, the energetic efficiency in controlled enviroments in which, looking for comfort for the building residents, smart systems like the one of illumination with LED bulbs were designed and implemented. This type of system was remotely controlled to set lighting parameters with respect to natural light or the number of occupants of these buildings [33],[34].

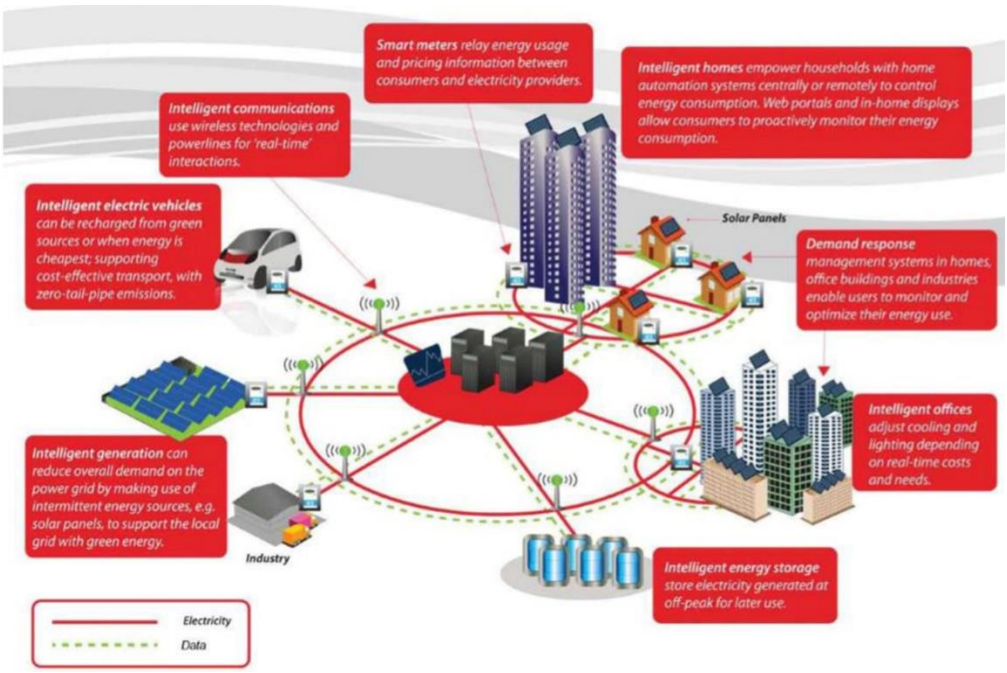

Figure 5. Smart energy system (IES) [3]

On the other hand, smart homes were another option to reduce energy consumption levels, a measure that helped regulate and control global warming; however, it was important for the citizen to adopt measures to reduce these energy consumption rates, aided by smart systems implemented in homes. For example, with the use of autonomous smart systems and sensors (Motion detection sensors, temperature, humidity, light) it was possible to control the appliances that will be used or the light sources of each of the spaces in the house [35],[36]. However, it was necessary to take into account the security of this kind of homes due to the amount of data handled, which can be easily accessed through the Internet if they do not contemplate and anticipate the necessary privacy challenges [37],[38].

- **Renewable energy**

The commissioning of solar panels as a source of renewable energy were managed through an smart grid [39],[40]. Figure 6 presents the general scheme of a micro-grid, where the means of alternative energy production are linked (solar panels, wind turbines, energy storage facilities, among others); the power lines for the energy transmission, together with a controller that distributes the necessary electricity to the residences, balances the electric consumption allowing an interconnectivity without interruptions to increase the efficiency and the reliability of the network. Therefore, obtaining the highest efficiency in photovoltaic systems allowed to reduce the demand of energy from the conventional electricity grid, which contributed to reduce the pollution indexes. The solar panel orientation and the appropriate inclination angle, on the other hand, guaranteed its greater efficiency and, consequently, the greater use of this energy to meet the purposes of the smart city [41],[42].

In search of reducing the abundance of solid waste and establishing an green energy impulse, was found as an isolated experience, an idea that started up and gave good results on a poultry farm in Singapore, where a anaerobic biodigester system was implemented with the purpose of producing biogas from the manure of its birds which allowed it to generate electrical energy, guaranteeing the self-sufficiency and sustainability of the farm. The excess of electrical energy that is not consumed, is sold to the city's electricity grid [43],[44].

- **Natural resources management and measurement of environmental parameters**

Water management is important to meet the daily demand of this vital liquid [45]. Therefore, this city inaugurated the largest seawater desalination plant in Asia to supply 25% of the population with the implementation of innovative technologies based on ultrafiltration membranes. The water monitoring quality is verified by a network of sensors to ensure that the liquid is in the best conditions to be consumed [46].

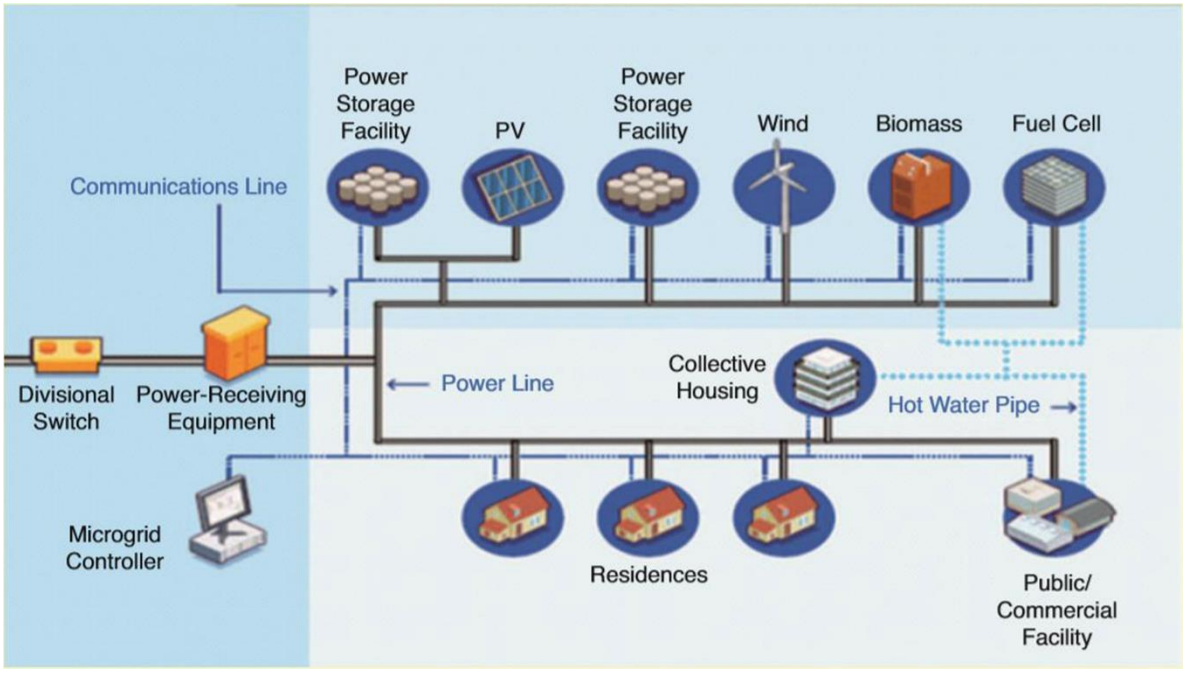

Figure 6. Typical scheme of a micro-grid [40].

On the other hand, the city has proposed to reduce the concentration indexes of fine particles in the air, the level of sulfur dioxide and the measurement of parameters such as noise, humidity and temperature [47]. Figure 6 shows different activities that can be controlled through the proper data management produced in the city.

3.3. *Government and Innovation Policies*

The government plays a decisive role in the decision making of a city and that is why it is one of the factors that can greatly boost innovation activities to help promote the production of knowledge that establishes the bases for the construction of new projects that benefit the community from the social, economic, cultural and political aspects [48]. The key to create innovation policies in Singapore was based on establishing the adequate means so this innovation could produce economic benefits and thus could support the academic and scientific scope, contributing to gradually improve the city, see Figure 8.

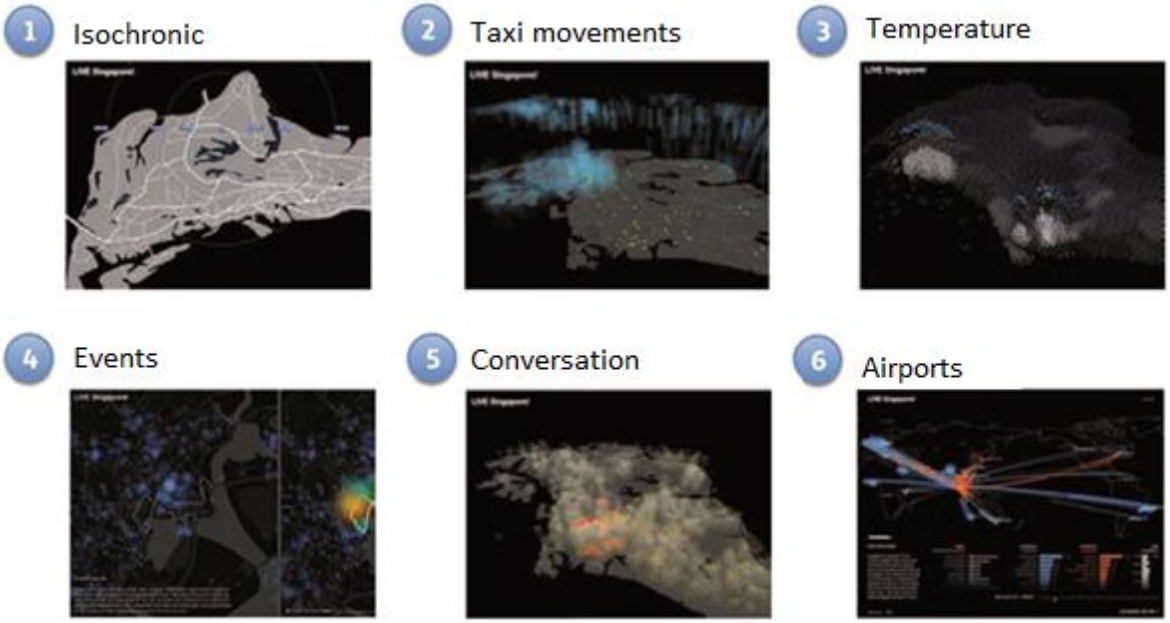

Figure 7. Singapore in real time [12].

Policies have been presented thanks to:

1. In 2006, a research, innovation and company council was launched to advice on I+D strategies and policies in Singapore.
2. In 2008, the National Research Foundation (NRF), founded to encourage greater innovation, launched the national research, innovation, and business framework for technology commercialization.
3. The 2010 science and technology plan aimed to strengthen the I+D base with a budget of US $ 9 billion; and this commitment in I+ D was reinforced by another five-year plan RIE 2015 with US $ 12.4 billion.
4. In Singapore, 61% of I+D was carried out by the manufacturing industry, followed by universities, research institutes and government institutions (29%).
5. These aspects of the innovation policy can be consulted in [49] and complemented with [50].

- **E-Government**

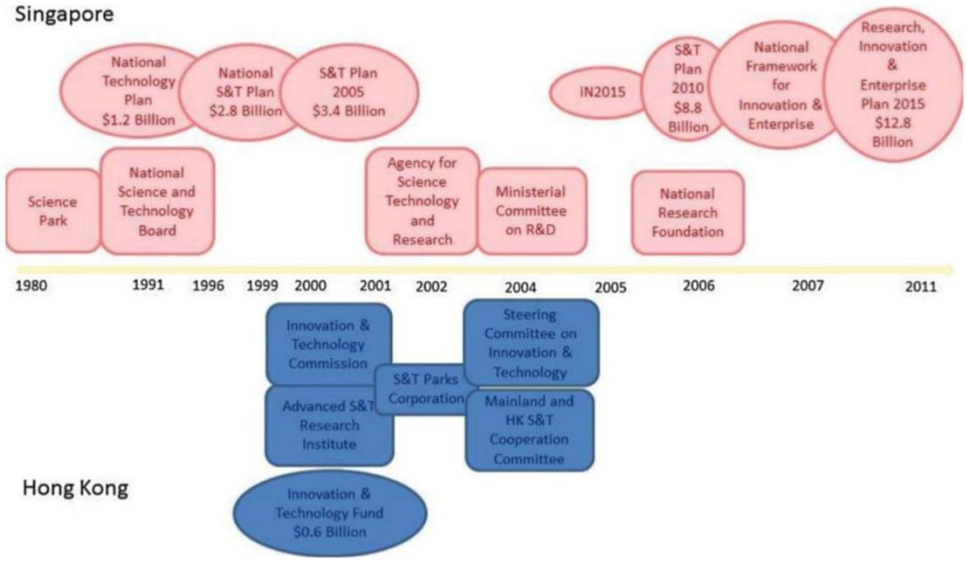

Figure 8. Singapore and Hong Kong innovation initiatives, [49].

From this perspective, Singapore has contemplated in its smart nation plan the integration of different government entities to create an environment of mutual cooperation where the city can be managed efficiently. The established government has seen the need to develop an integrated data exchange platform to take advantage of the existing smart sensor network and thus provide accurate data on the city operation where the information collected is processed in the best way to enable the efficiency in the city administration with respect to the systems that it must control. In 2013, SCDF (governmental agency) responded to more than 4,000 fires, which represented a decrease of 7.8% of the cases in 2012. The year 2013 registered the lowest annual figure in 20 years. Similarly, the benefits of surveillance cameras can be measured by the number of cases of crimes that has helped solve and, ultimately, to reduce the rate of urban crime. Several newspaper articles from Singapore revealed that the cameras installed in the blocks of *Housing and Development Boards* since 2012 have helped solve more than 430 cases and provided crucial information for 890 cases of criminal investigation [3].

- **Directive intervention**

Aimed to achieve predetermined results by making changes in investment and production patterns in selected industries. A clear example was that by promoting the high-tech economy, the government provided funds for research and development, established public research facilities and helped transfer the result to private sectors, [49].

- **Facilitative intervention**

The objective was to create positive environments for private companies by providing public goods such as infrastructure and education. The facilitative government tried to promote innovation by building institutions in order to promote a healthy culture and targeting policies to overcome private

investment obstacles instead of directly influencing innovative behavior through highly interventionist measures, [49].

3.4. *Smart health*

The population birth rates in the city were reduced over the years, and it is for this reason (a great challenge) that in order to guarantee timely attention to the public, mobile applications have been developed to prevent chronic diseases, planning telehealth[8] tools and ICT solutions (Corresponds to major political initiatives at both national and autonomous levels, linking different government entities with the health sector [51]) to improve the logistics of patient care in hospitals [5].

3.5. *ICT*

Computer and mobile applications have revolutionized the teaching methodology in the classroom, allowing to build a collaborative knowledge about contextual mobile learning. It has been possible to create applications that link the student and help him establish complex relationships with his environment to facilitate the resolution of initial conflicts and failures, as well as the way in which he must develop in his environment, allowing him to learn in a new form, the way in which he must take decisions to achieve the proposed goals [52].

- **Machine learning**

The data produced in a smart city can be used for different actions and approaches, the high level of processing that can be achieved with this data can provide key information that helps to provide welfare to citizens. A data application is presented in a study to find the thermal comfort that a

[8] It describes a wide range of diagnosis and management, education and other related fields of medical care that is provided through technology. Includes: Dentistry, counseling, physical and occupational therapy, home health, among others.

person feels at their work place or home, which is reflected in a daily use / energy consumption to maintain this comfort [53],[54]. The data based prediction is collected from 4 public city residential buildings to find an optimal balance between energy use and thermal comfort, helping to reduce energy consumption in buildings due to the high energy consumption presented by the frequent use of ventilation systems [55],[56],[57],[58].

The other approach that can be given to the data is related to the study of faults in the city railway system to determine the system reliability and to decide the maintenance cycle based on the average estimation time until the system failure [59].

- **Big Data**

The problems in a city can be solved in different ways; among these is the implementation of information technologies that capture and transfer information between different places [60],[61]. Performing fast information processing acquired from all kinds of sensors implemented in the city has required, in some cases, data simulation to know the trend towards a specific result type and then make the most accurate decision according to the needs [62]. Based on this, Big Data has been a tool that processes sensor data located in strategic locations [63],[64]; and the use of this data has been oriented to the solution and facilitation in the waste collection and treatment to improve the quality of the environment [65]; through the creation of databases that store the places where this waste is generated, and with the ecological grids implementation, viable commercial industrial symbioses have been established to obtain a benefit from the waste collected [66],[67].

On the other hand, Big Data has contributed with the transport system analysis, modeling and planning [68],[69]. From this perspective, it is necessary to start from a reality that focuses on being able to use the data to guarantee adequate transport routes planning, understanding that there are

inherent limitations to obtain the best results in terms of improving mobility and it is only with the formulation of policies and the taking of right decisions that can guarantee a better information understanding to be processed in order to achieve optimal results that adjust to the citizen needs to mobilize in urban areas [70].

In another sense, it is crucial to bear in mind that an adequate data protection generated in a smart city must be considered in order to protect vital information about citizens according to the procedures that are carried out through the Internet. [71],[72]. Protecting this data guarantees the formation or strengthening of the relationship between citizens and the local government and allows attracting investment from private companies, foreign investors and greatly improving the provision of basic and complementary services required by citizens.

- **Sensor networks**

The sensors used in the city transmit information based on high-speed wireless networks where cameras, GPS devices and other sensors are implemented in different places, as well as in taxis, to help manage traffic and improve the prediction of future congestions helping to the calculation of the most optimal routes to achieve an efficient vehicular flow [73]. The citizen's use of technological devices (smartphones, tablets) means that they become the best sensors in the city (Participatory Detection Platform or PS), and, thanks to the fast processing of these devices, it is possible to offer information in real time about certain events that occur on a day-to-day basis. One of the applications of this platform is the development of a Transport Travel Measurement System (TTMS) that provides data anywhere and large scale coverage to demonstrate the paradigm of PS in the evaluation of the travel quality [74],[75].

- **Internet of things**

The IoT, which consists of a network of sensors located at strategic points in the city, has allowed an adequate information flow that let know in real time the state of a particular area [76],[77]. The sensor interconnection and the data transfer they produce to the cloud is a challenge presented by smart cities [78],[79],[80]. The SENSg[9] sensor nodes were used in Singapore in 2015 to conduct large-scale experiments on environmental factors and to allow the collection of daily activity data of up to 50,000 students. The project objective was to find a solution to the large scale of environmental sensors urban deployment that, helped with the design of the integrated algorithm, reduced the data amount that must be moved and processed in the central servers. The implemented solution solved the problems in the environmental sensors urban deployment and with the integrated algorithms design, they demonstrated an important advance in the capacity to implement machine learning code [81].

Therefore, the IoT has a large field of action in the activities that are carried out in a city; among these is to help reduce the level of energy consumption in industrial areas or factories [82],[83]. In the study carried out by [84] a software application for energy efficiency real time monitoring in production plants is presented, finding valuable benefits such as the abnormal occurrences real time monitoring and the help it provides to the energy managers to integrate best practices into day to day operations eliminating possible waste of energy in operations.

In another sense, the hydroponic vegetables cultivation in Singapore is a measure used to supply the food demand in the city, which through the use of sensors, actuators and microprocessors is used to control water quality and luminosity of these crops, proving to be a self-sustaining and low cost source that, if implemented, can significantly reduce labor and operational costs, while

[9] Custom sensors with a hybrid cloud infrastructure.

increasing livestock production and profitability, contributing to the sustainability and habitability of the city [85].

4. Discussion

The future vision with the approach of strategies to seek and achieve the objectives proposed in a city, establishes the bases to develop initiatives that promote innovation and citizen participation for the projects implementation that, financed and supported by government and private entities, achieve continuous consolidation for the construction of an efficient and optimal city for the lives of citizens; This has been the case in Singapore. Here began to implement projects since the seventies of the last century to advance urban infrastructure works which has allowed it to be listed today as one of the best cities to live.

Likewise, citizen participation was fundamental to achieve the relevant changes in the city, because were and are its inhabitants who interact continuously with smart systems that are implemented and it is precisely because of this interaction that an information flow is created allowing its timely management, supervising, controlling and acting at all times to achieve a single objective to identify the improvement of the *people life quality*, among many other factors.

The urban spaces that are taken as reference of smart cities have strengthened their competitive advantages supported by factors such as social innovation and a strong research capacity to find solutions that allow them to overcome the obstacles of the city, finding a sustainability approach for the city development of a social, economic, and political environment.

In an smart city it is essential to use efficient communication technologies with a large scale network architecture deployed for the internet of things, accompanied by adequate transmission

techniques and means to avoid connectivity problems, guaranteeing a good information reception that, with the use of machine learning, improve the management and the amount of information that is processed in the central servers.

The mobility system is one of the main indicators of development in a city. The services for this integration go from tickets, payments, and the use of ICT to facilitate the use of the service. Encouraging and developing this kind of public transport solutions brings an important benefit, such as the increase in the traveler's level using the system, which significantly reduces the use of private vehicles as an alternative to transportation. Realize a total or partial integration of this system is a challenge that must be faced to advance in terms of social and economic development.

As an evaluation proposal, or determination of success case, Singapore was considered in this document as a smart city because it has managed different city systems to continuously improve infrastructure, environment, social and economic aspects to offer good *life quality* to its inhabitants. However, it is necessary to establish a concrete evaluation model for Singapore, given in [7], which indicates a quantitative assessment in terms of GMSDIL (*Governance*, *Mobility*, *Sustainability*, Economic *Development*, *Intellectual* Capital, *Life* Quality) that is used to classify cities as smart. The classification is presented as follows:

Table 1 describes the axis and corresponding factors that are considered to evaluate a city as a smart city. Each factor is evaluated on a scale of 0 to 4 and the factors of each axis are evaluated as follows:

$$G = (g1+g2+g3+g4) / 4 \quad (1)$$

$$M = (m1+m2+m3+m4) / 4 \quad (2)$$

$$S = (s1+s2+s3) / 3 \quad (3)$$

$$D = (d1+d2) / 2 \quad (4)$$

$$I = (i1+i2) / 2 \quad (5)$$

$$L = (l1+l2+l3) /3 \quad (6)$$

SMART CITY AXIS		FACTOR	
G	e- Government and e-Governance	Electronic Headquarters	(g1)
		Transparency	(g2)
		Interactive Street	(g3)
		Citizen Communication	(g4)
M	Mobility	Sustainable Urban Mobility Plans	(m1)
		Public Transport Multimodal Integration	(m2)
		Deployment of Alternative Means (Bicycle)	(m3)
		ICT in Traffic Control	(m4)
S	Environmental sustainability	Energy Efficiency	(s1)
		Water Consumption Efficiency	(s2)
		Emissions	(s3)
D	Economic Development	Open Data	(d1)
		Innovation Ecosystem	(d2)
I	Intellectual Capital	Wi-Fi as a municipal service	(i1)
		Training	(i2)
L	Life Quality	Health and Sanitation	(l1)
		Universal Accessibility	(l2)
		Deployment of various ICT measures for the enjoyment of the city	(l3)

Table 1. The axes of the smart city and the evaluation factors used [7]

Finally, (7) is applied to obtain the corresponding value to determine the classification of the city as follows:

5. Cities rated as *Smart City*: Rated above 2

6. Conventional cities: Rated with 2
7. Cities below the average: Rated below 2

$$SC = (G + M + S + D + I + L) / 6 \qquad (7)$$

Figure 9 indicates the values of each factor for each axis, where is applied (7) and a score of 2.46 is obtained, which clearly indicates that Singapore is valued as an smart city.

G		M		S		D		I		L	
g1	3	m1	4	s1	4	d1	2	i1	1	l_1	3
g2	3	m2	4	s2	4	d2	4	i2	2	l_2	1
g3	1	m3	1	s3	2					l_3	1
g4	2	m4	3								
	2,25		3		3,333333		3		1,5		1,666667
SC	2,458333333										

Figure 9. Values applied to (7) indicating the qualification of Singapore as smart city

8. Conclusions

Mobility

The reliability of the rail system in Singapore is important so that citizens can move around the city, which is why deciding intelligent maintenance strategies especially in the communications part, is crucial to comply with the regular operation, avoiding delays in the service.

The travel demand data for a large-scale model in Singapore's rapid transit train system allows to understand the congestion dynamics in this transport means and enables transport operators to accurately estimate passengers comfort and satisfaction to build efficient transportation strategies.

The mobility trends are driven by several factors, among these are the social and emotional. The choice of one or another transport mean depends to a large extent on how it affects the mentioned

factors. Taking this fact into account, it is possible to understand and comprehend mobility patterns that make it possible to understand how to reduce the traffic levels congestion in the city to offer better and more efficient public and private transport services.

Energy efficiency

The data use generated by the citizens turns out to be an option to optimize the energy consumption that, with the help of specialized algorithms, obtain prediction accuracies from 73.14% to 81.2% in Singapore building thermal comfort. These data, used in modeling and specific studies, establish the bases to carry out efficient energy operations, which, together with the use and development of smart electricity grids, make it possible to take advantage of and manage energy to meet the citizen’s needs for electricity consumption.

The green energy generation for lighting purposes can be improved with more complete and sophisticated systems such as solar plants, which consist of mobile solar panels that, by means of sensors, follow the sun's illumination, allowing a higher rate of electricity to be stored by the monitoring carried out on this light source. The results obtained showed that a solar plant can produce 3.2% more electricity than a conventional solar panel.

The energy saving in homes makes it possible for electric saving levels to increase, but it is important to consider people's behaviors and perceptions to make it more efficient. By designing smart systems in the home with modules that involve artificial intelligence, it is possible to obtain greater control of household appliances. In Singapore to achieve a successful smart home solution it is necessary to integrate services and public service sectors such as smart grids and health sectors.

Technological infrastructure

The use of SENSg sensor nodes helps to extend a large number of city environmental sensors with a large scale IoT deployment, in addition to this, the design of integrated algorithms allows to reduce the amount of data to be processed demonstrating the ability to use automatic learning code to optimize the use of central servers, which translates into the rapid display of the analysis and / or statistics generated by the data obtained from the sensors in the face of changes in city environmental parameters.

The Big Data applications are varied, one of them is finding the exact points from the location, type and quantity of materials where can be performed industrial symbiosis (capture, processing, and waste reuse to convert them into resources) in a city industrialized. Although more research is required to extend the system, the results demonstrated the feasibility of the approach to develop a proof-of-concept program using Singapore as a geographic region.

From all the above, have been built relationships between the different systems and elements that Singapore has incorporated to become a smart city. Figure 10 shows the *integration and complement* of *systems* that gave the strength of a smart city. The mentioned systems are highlighted in blue and correspond to smart mobility, energy efficiency, government and innovation policies, smart health, and ICT. It is evident how, through ICT, it is possible to provide these systems with new solutions and continuous implementations to make them increasingly efficient. The mental map that represents this figure, is established from the areas in which the city focuses, how through the use of technology it is possible to address the problems of citizenship to provide effective solutions. The IoT and Big Data with data management, make possible the innovation and adaptation to change that allow to better manage the city. The relationships between

the systems are established according to the solutions provided by the city to make this environment a more sustainable medium.

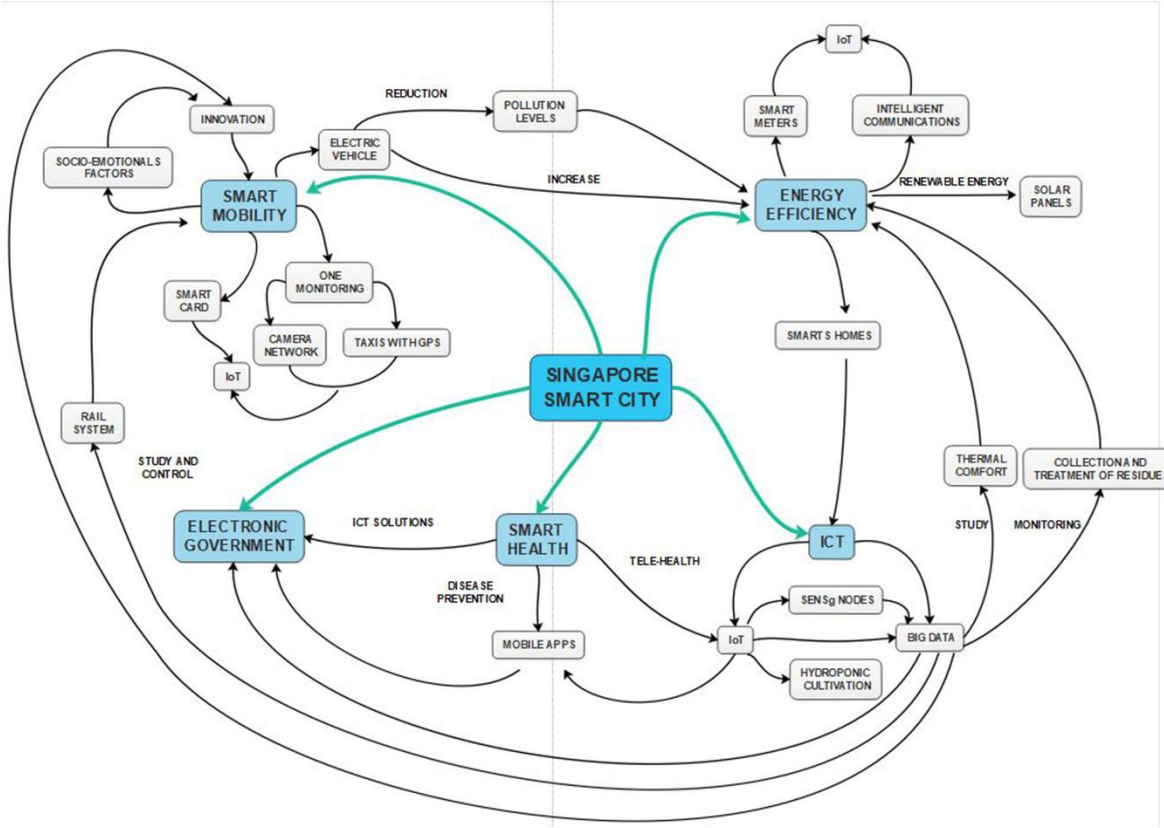

Figure 10. Integrated and complementary system network and elements that make Singapore a success case as smart city. Source: own.

The relationship between smart mobility, energy efficiency and ICT is presented as follows: the smart mobility system with the use of the electric vehicle increases energy efficiency (reduction of greenhouse gases) and smart communications make possible acquire data for transfer through the IoT; in this phase you can make a data processing by means of Big Data and from this point can be taken the statistics of these data to an E-Government management for the appropriation of this information by the established Government or, on the other hand, with these processed data generate innovation in the transport system to start again from the smart mobility system, presenting a global city system feedback (it is the objective of an smart city) that increases its efficiency for the achievement in the improvement of the citizen life quality.

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