Emerging Data Driven Smart City and Its Solutions for Sustainability: The Case of Cuenca-Ecuador

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Abstract. The rapid urban growth of cities has produced several economic, social and environmental problems. This has brought the need to seek alternatives to develop more sustainable, resilient and equitable cities. One of the models that present one of the solutions for these sustainability problems are data driven sustainable smart cities, which are smart cities that use big data to generate a large amount of information that once it has been collected, stored, processed, and analyzed by different institutions with technical and specific competencies, implement actions to achieve their sustainability. Although there is no extensive literature on the characteristics of these cities, there is a theoretical framework that explains the characteristics of this type of cities. The objective of this paper is to identify the potential of the city of Cuenca in Ecuador to become a data driven sustainable smart city using this theoretical framework. The research is descriptive using the city of Cuenca as a case study, for which different sources of secondary information such as public documents about the city were used. As a result, it was identified that the city of Cuenca uses sensors to monitor traffic, air quality and noise, the implementation of smart lighting systems and the creation of a digital platform to improve the management of public services such as water, electricity and garbage collection, which makes it fit in certain characteristics to the model of a data driven sustainable smart city. However, one the main factors to fit the data driven sustainable city is the national and local context of a city.

Keywords: Data Driven · Smart City · Sustainability · Big Data

1 Introduction

Currently, more than half of the world's population lives in cities, and it is estimated that by 2050 almost seven out of ten people will live in urban areas. This rapid urbanization process has brought new problems, such as social inequality, traffic congestion, environmental pollution and health problems [1]. These problems create the need to seek mechanisms to achieve more sustainable cities. Sustainability is understood as "what makes it possible to satisfy the needs of the present without compromising the ability of future generations to satisfy their own needs" [2]. That is why the United Nations has established the Sustainable Development Goals (SDG), among which is SDG 11, which seeks to achieve more sustainable and inclusive cities through the development of more innovative models for cities [3].

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The use of ICTs has become in one of the tools to achieve more sustainable cities. First, because thanks to the development of smart cities, which main component are stable, secure, reliable and interoperable technologies that are integrated into a significant volume of applications allow different services to be provided in an efficient and sustainable manner [4, 5]. Thanks to recent advances in the field of Internet of Things (IoT), artificial intelligence (AI), digital twins, robotics, and smart electricity networks and meters are driving and supporting the development of smart cities at world scale. Second, thanks to ICTs through the IoT [6], which is a rapidly expanding network of devices with embedded sensors and software that connect with each other and share data, it allows billions of devices and objects equipped with smart sensors connect with each other and collect information in real time and send this data, wirelessly, to centralized control systems for subsequent decision making [7, 8]. Third, thanks to ICTs, everyday millions of digital data are generated worldwide that different institutions, whether public or private, can store for later use. This accumulation, processing, study and use of data on a large scale is called Big Data [9]. The data obtained thanks to Big Data is undoubtedly a valuable source of information for the private sector, which until now has been the one that has benefited the most from its use, but Big Data is also called to play a key role in sustainable development from the public and institutional sphere. Big Data for sustainable development seeks to gather, cross-reference and relate data from physical components with data on social components [10]. These data, in turn, are extracted mainly from satellite photos and public databases, requiring public-private collaboration. As a result, when crossing all these data, it can help to avoid geopolitical conflicts, understand human behavior in the face of natural disasters or humanitarian crises and understand vulnerability and resilience in different situations [11].

Smart cities are taking advantage of the power of big data, for example, to manage the mobility and behavior of citizens in a much more intelligent way [6]. This is how the term “data driven smart city” has emerged, which is a city that uses the data generated by different technologies in order to improve and optimize its operations, services, strategies and policies in a specific area [12]. For example, the data generated by big data can improve security, since it can be used to know which are the most conflictive areas of a city and make decisions about it [13]. This data can also encourage sustainable growth through proper city planning, as maps can be created based on the needs of different parts of a population. The data also allow optimize operations and make better decisions in traffic management planning. For example, cities like Madrid, Barcelona and Valencia are already taking advantage of electric mobility in their urban buses [14]. Thanks to big data and the interconnection between teams, cities can access information they have never had available before and offers the possibility of making better decisions in real time. These data can also improve the environment due to air quality sensors, efficient buildings, among others. All these benefits that the information generates through ICTs brings the term "data driven sustainable smart cities", which is an innovative city that uses ICTs together with the interconnection of urban systems that allow controlling its resources in a sustainable way in order to improve their citizens’ quality of life [15].

However, currently a large body of literature present exclusively the benefits of big data and the Internet of Things in a smart city. Few research focuses on the solutions that big data can bring to sustainability in smart city context. One of these few investigations on how big data can generate solutions for the sustainability of a smart city is the work of Bibri and Krogstie 2020 and Bribi 2021 in which the integration of sustainable urbanism and smart urbanism was analyzed and identified a conceptual framework for data-driven sustainable smart cities [16]. This paper aims to explore the potential of the city of Cuenca to be considered a data driven sustainable smart city. The importance of this research is that each city has a particular context for which it is necessary to analyze its specificities in terms of big data generation and how it can be used to help achieve its sustainability.

This paper is structured as follows. Section 2 provides the details of the data-driven sustainable smart cities. Section 3 presents the methodology adopted for this research. Section 4 presents the findings of elements of each dimension of the conceptual framework applied to Cuenca. Finally, this paper concludes.

2 A Conceptual Framework for Data-Driven Sustainable Smart Cities

2.1 Data Driven City

Collecting large amounts of data, processing it and sharing it in real time in the form of relevant information generates added value for a city. The data, converted into information for decision-making also facilitates synergies and interoperability, within the city itself and with other supra-municipal services and systems, such as transport, energy or health and drives innovation in areas such as mobility, safety, efficiency and energy [17].

Mobility
In this line of action, data driven city is put at the service of an integrated logistics and transport system for a city, efficient and with low environmental impact. It includes traffic management, the urban distribution of goods and the management of sustainable, safe and interconnected transport systems, which integrate buses, trams, trains, subways, bicycles, scooters and pedestrians, allowing to easily change modes of transport and prioritizing clean and non-motorized options, in addition to providing users with useful information in real time [18]. The managers of these systems use enabling technologies to provide a better service and receive feedback from citizens, who can provide information to the system in real time, which in turn allows for better service planning.

Security
Smart cities must create safe spaces, protect sensitive infrastructures and areas from threats and be able to react effectively and quickly in the event of emergencies. There are video surveillance systems and security systems based on and supported by the use of cameras, cybersecurity against attacks on essential public services, transportation

security, command and control centers for emergency management, public alerts, technological location systems and video surveillance solutions applied to the protection of heritage and infrastructures [19].

Energy Efficiency
In this line of action of a smart city, everything related to the environment of cities, are the greatest generators of impacts, both due to the consumption of water, energy and raw materials, as well as the generation of waste and pollution. However, for this type of problem, there are solutions for the promotion of renewable energies, intelligent measurement systems for energy and water consumption, pollution monitoring and control, the renovation of buildings and urban equipment, as well as the efficiency, reused and recycling of resources [20]. In this sense, there are solutions for the integration of all urban services in integrated systems, which not only put technology at the service of providing services, but also for their operation and management. On the other hand, urban public lighting deserves special attention. For this, it is important to have the connectivity infrastructure for other services, given its regular distribution throughout the entire city, its permanent connection to the electricity grid and its elevation above sources of distortion and communications interference [21].

2.2 Data Driven Sustainable Smart City

One of the research about data driven smart sustainable city is the one of Bibri (2020) who points out that a data driven smart sustainable city is a city that has several components of ICT and use all these technology and solutions in order to generate, store, process, analyze and take advantages of urban data to make better decisions in different areas with the purpose to improve quality of life of its citizens [12]. The results of the research was the design of a framework for data driven sustainable smart cities that is composed of several dimensions interrelated such us technology, competences, processes and practices as it is presented in figure [16].

This theoretical framework based on the information generated from two Spanish cities presents dimensions such as technology, the competences of different actors and the processes and practices that can be implemented. All this interaction between the existing technologies of a smart city allows the generation of different operations and services which are managed by different institutions or actors with specific skills and abilities that seek to apply sustainable and equitable practices to improve the standard of living of their citizens. The data driven sustainable smart city model is based on all this interaction and integration of dimensions, which will be explained in detail below.

Technology
Within a successful smart city system that generates data, the technological infrastructure has been identified as a fundamental pillar in the model, which allows the collection, storage, processing and analysis of data. In this sense, the exchange of data between different actors and the creation of solutions based on the information analyzed is important. At this level there are platforms applied by the administration and control of a city [4]. As part of the infrastructure is everything related to accessibility such as the density of the Wi-Fi network, internet access, level of fiber optic penetration, number of wireless

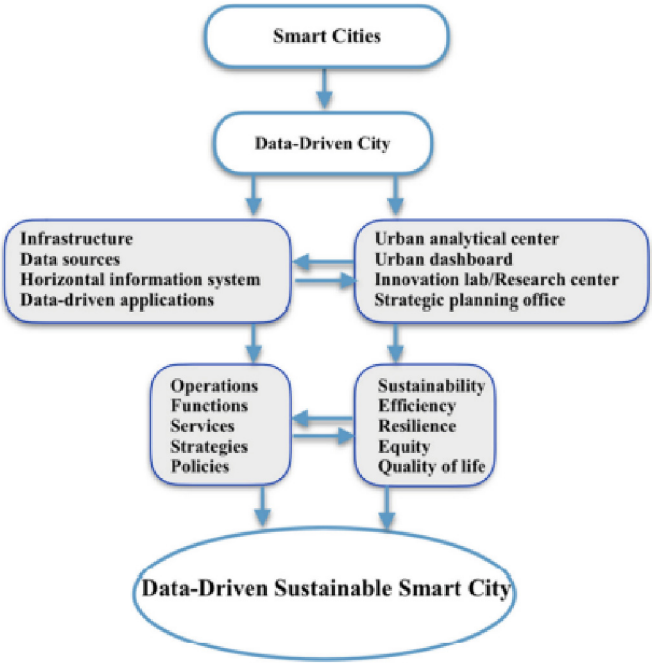

Fig. 1. A conceptual framework for data driven sustainable smart cities.

internet points in public places, broadband speed, capacity networks among others [22]. An important aspect is the sources of information, such as the presence of open and online data, electronic and mobile payment systems, use of social networks, Internet use as a percentage of the population, proportion of computer owners, proportion of residents with smartphones and number of visits from municipal services on the web portal. Another tool is surveillance sensors and cameras, in highway traffic, public transit, parking lots, public lighting, cleaning and garbage collection, and control of polluting gas emissions [4, 23].

Technology is a very important dimension of the conceptual framework because it evolved all related to a cyber-physical system that offers comprehensive management of all the elements that it encompasses through different technological tools that help collect and analyze data to meet the objectives of efficiency, sustainability, productivity and safety [24]. Intelligent infrastructures are based not only on their physical structure, cabling, sensors, among others, but also on principles such as data, applications, analytics, feedback, and adaptability [4, 6]. It is an infrastructure that collects data, processes information, takes appropriate actions in a completely autonomous and dynamic way. This classification usually includes smart grids, smart transportation, smart buildings, smart civil infrastructures, especially to provide basic services, security, and citizen participation.

Intelligent Networks

An intelligent network is one that can efficiently incorporate the behavior and actions of all the users that are connected to it, in such a way there are few losses and a high quality and security of supply. An example would be the Horizontal Information System, which is software for managing the information of one or several administrative procedures that affect the scope of several departments, even when the competence in the management and definition of the affected procedures falls on a single department [25].

These systems generally use sensors that store information at different points in a city. Some examples of these systems are Sentilo and city OS. In this area is the transport network that, thanks to its intelligent network, enjoys greater automation, integration and management of all the devices connected to it, thus achieving an efficient and sustainable distribution. Mobility technologies in cities such as Barcelona and London stand out as they use data driven technology for transport. Hybrid buses are also used to decrease emissions and a bicycle sharing system that can be available for citizens to go for short trips in the city [26]. There is also a Biking app that check the availability of bicycles. Another example of these technologies would be the case of the city of Bogotá, which uses the Intelligent Transport System (SIT)20, which is made up of a set of technological tools that serve to collect, store, provide traffic information and monitored in real time [27]. The Traffic Management Center is the place that Bogotá mobility system is managed for decision-making and dissemination regarding accidents, congestion, the environment and citizen perception based on the integration of information, knowledge, technologies and processes. The generation of these intelligent transport systems allows acquiring much more friendly transport with the environment such as electric buses. One of the greatest examples is Spain, which in many of its cities has emigrated from traditional buses to fully electric buses, cities like Madrid, Barcelona, Sevilla and Zaragoza follow this trend [14]. The growing number of people living in cities, makes necessary to [4, 6]. The use of intelligent traffic lights, it is possible to distribute the volume of vehicles, improving traffic and promoting more sustainable mobility. For example, countries like China are already beginning to carry out this type of initiative, implementing intelligent traffic lights, which are capable of decongesting large urban areas [28]. These traffic lights collect information such as the number of vehicles that have approached the traffic light, waiting times, or the state of traffic. The information is processed and allows the traffic light to decide the optimal moment to stop or move traffic, thus avoiding traffic jams [6].

Smart Energy

Thanks to energy technology, it is possible to automate, control, monitor and optimize the energy of cities. To achieve this, it is necessary for cities to have an efficient infrastructure made up of sensors, advanced technology meters, renewable energy sources or control and analysis systems. These types of methods multiply the savings and efficiency of energy in cities, one of the most valuable resources and the one that generates the most waste. One of the cities using this technology is Oslo in Norway, which has 650,000 LED bulbs that are connected to processing stations [29]. These bulbs can intelligently adjust the power of the light according to the need of the moment. Another case of cities that apply this technology is Singapore, that through hundreds of thousands of sensors installed in various regions of the country permanently monitor energy consumption, waste generation and the use of drinking and residual water, over time [30]. All these

devices provide public service providers, residents, the government, industries and civil organizations with exact information on the use of resources and services, thus it is possible to identify sources of waste, reduce costs, make more efficient delivery, better distribution of resources, and above all, creating awareness among the population.

Citizen Security
Another of the most controversial global issues in recent years is the application of Artificial Intelligence in relation to citizen security. The increase in surveillance devices on streets around the world generates acceptance and rejection in equal parts. However, today's smart cities take advantage of technology in a more realistic and effective way. For example, through security and surveillance cameras, models can be applied that alert about certain suspicious movements or actions by citizens. Clear cases can be violent acts or robberies, thus resulting in great allies in reducing crime. Other elements such as facial identification have applications from simple capacity control to the identification of individuals in response to criminal cases [31].

Citizen Participation
Citizen participation is a collaboration tool between citizens and governments. To facilitate citizen participation, it is not only about incorporating the use of new technologies and promoting digital governments, but also about facilitating physical and virtual spaces for citizens to participate in the entire process of proposal, execution, and evaluation through the use of new technologies. For example, Medellín Ciudad Inteligente, encourages citizen participation through free access to the Internet in public spaces and facilities. The open data platform Mi-Medellín also allows the collection and use of data for the co-creation of the city. Moreover, the city has an Intelligent Mobility System, A Early Warning System, A Noise Monitoring Network, An Air Quality Network, and the Integrated Metropolitan Emergency and Security System, citizen-oriented initiatives that, through ICT, they respond efficiently to security, mobility and environmental problems [32].

Competencies
Data oriented competencies can be technical and institutional, which are characteristics and abilities can allow the right functioning, management and planning of different activities that can be interrelated. The institutions that develop different competencies can be training centers, study institutes for the generation of urban information, universities, strategic planning offices, analytical centers and urban dashboards [16]. These institutions or departments have the mission of processing the information and then analyzing it to make decisions to solve some sustainability problems. For example, the Analytical Centers operate through a smart city board, whose objective is to create innovative platforms for the use and application of big data. In the case of Urban dashboards, they are very useful for collaborating in the analysis of data that can be interpreted by experts or not. Other key institutions in the development of competencies are strategic planning offices, which are generally public and play a fundamental role in the development of sustainable projects. Likewise, the academy is key to managing big data information, since many universities create training programs for the creation or management of big data information and sustainable projects. Universities usually have Innovative Labs and Research Centers, that seek to develop and improve solutions for sustainability. For

example, in Brasil, Sau Paulo, there is the Secretary of Innovation and Technology that has the MobiLab laboratory, which is an organization recognized nationally and internationally for innovation in the urban mobility segment, whose open data allowed the launch of a series of applications and tools focused on transportation and traffic [27]. In 2019 it became Mobilab+, focusing since then on the search for solutions related to education, health, housing, well-being, the environment and mobility, among others [33]. In this sense, these institutions can provide real-time information to users about transportation schedules, bicycle availability, weather, air pollution, and traffic level. All this information can help in the planning of a city, if there is a clear planning of the management model of a city and the role played by each of the actors involved.

Processes and Practices

The processes and practices are totally related to the technology and competences that a smart city may have. For example, depending on technology and infrastructure that a city has, different services can be provided and various operations can be carried out or specific strategies can be created and even different policies can be applied. These operations are generally related to transportation, traffic congestion, urban infrastructure management, citizen security, gas emissions, equal access to education, health, other social services, citizen participation, and urban planning. In the same way, the practices that can be applied in a smart city to make it more sustainable, efficient, equitable and resilient depend on the different skills and abilities developed by the different institutions involved.

3 Methodology

This is a descriptive investigation, since a specific case study of the city of Cuenca is used, which has been chosen because in 2022 it was evaluated and recognized as the best smart and sustainable city in Ecuador [34]. This is based on the International Model of Sustainable Smart Cities of the International Telecommunications Union of the United Nations and evaluated by the Ministry of Telecommunications in 2022 among 60 cities in the country. This indicates that this city is applying technologies for the development of different sustainable projects in the social, political and environmental areas. In this sense, development plans, programs, projects, public documents and other secondary data of the city were reviewed. In the same way, the research is of a deductive type since it goes from the general to choosing a theoretical framework on data driven sustainable smart city and adjusting it to a specific case study such as the city of Cuenca.

4 Results of the Case Study of Cuenca

The conceptual framework for data driven sustainable smart cities, as presented in Fig. 1, generates data in different areas. The generation, collection, management and control of this data depend on two large dimensions such as Technology, which implies the physical and non-physical part of ICTs, which are in charge of the different operations, functions and services in the city. The other important dimension is the competences that are generated from the different actors that can be planning departments, universities, urban

analysis centers and research centers which are in charge of managing the information generated by a smart city in order to use the information in sustainability projects. That is why, based on this framework applied to Cuenca (Fig. 2).

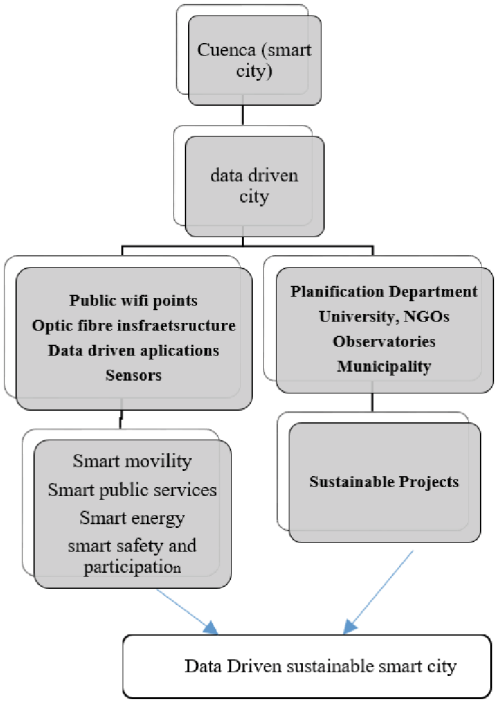

Fig. 2. Cuenca a data driven sustainable smart city

Technology

Internet coverage in Cuenca is relatively good. Most of the urban areas of the city have access to high-speed internet through technologies such as ADSL, cable, fiber optics and Wi-Fi. The most popular internet provider companies in the city are Claro, Movistar, CNT and TV Cable. For example, there is an infrastructure of 85% of fiber optics in the city and according to the 2019 Multipurpose Survey, 79.02% of households in the urban area of the city have internet [34]. In addition, the city has more than 600 public Internet points in parks, markets, squares and train areas [35]. This internet coverage allows the city to offer services with a mass focus, applying emerging technologies such as IoT and Big Data.

Transport, Traffic, and Mobility

Cuenca is a city where points of interest are within short distances. It has accessible and safe routes and attractive routes that allow people to enjoy the urban landscape, more direct routes that help optimize travel time and correctly resolve conflicting points.

Its mobility infrastructure allows it to articulate with other modes of transport. In the downtown area of the city, there are sensors to monitor vehicular traffic, as well as smart lighting systems to save energy [36]. The city also has 100 km of cycle paths, and non-polluting transport such as the Tram that allows reducing the carbon footprint as well as the collection of waste and recycling [34]. For example, there is the Cuenca Electromobility Plan born from the Transformative Urban Mobility Initiative (TUMI) which, through the German Cooperation for Sustainable Development (GIZ), seeks to accelerate the adoption of sustainable mobility in the world supporting developing countries [37]. In addition, the city has the "BiciCuenca" public bicycle program that adds to the initiative to build safer spaces and streets for cyclists by redesigning street intersections with an accessible design [38]. Moreover, with the purpose of providing support in the traffic operations of the city, the Mayor's Office of Cuenca and its Mobility, Transit and Transportation Company, EMOV EP, through the use of drones, detect mobility difficulties on the roads with the highest circulation [39]. During overflights, the images and videos captured by the drones are sent to a Command Center where it is coordinated with group leaders and supervisors so that contingency plans are immediately activated that allow a better vehicular flow.

Environment

It was pointed out in the Cuenca Air Quality Report 2018, the Cuenca Air Quality Monitoring Network has generated reliable information through internationally recognized methods and procedures. Since June 2012, the Basin Monitoring Network operates an automatic station installed in the Historic Center. This infrastructure records the levels of air pollution and the values of the main meteorological parameters in real time. Since June 2016, they have also been operating with automatic sensors for fine particulate matter, which record the concentrations of this pollutant in the area of influence of the Cuenca Industrial Park [40].

On the other hand, within the urban area there are levels of auditory emissions higher than the norm, with few exceptions, especially at night time for measurement. It is worth mentioning that as part of a noise control project, the platform http://gis.uazuay.edu.ec/proyectos/ruido-continuo/ was created, which works in real time, reporting the noise level in 7 stations located in different points of the urban area of the city [41]. In addition, there are sustainable energy projects in which solar energy systems have already been implemented in various public and private buildings.

Citizen Security

It is the function of the Municipal local Government to create and coordinate municipal citizen security councils, with the participation of the National Police, the community and other organizations related to security matters, which formulate and execute local policies, plans and evaluation of results on prevention, protection, security and citizen coexistence. The Cuenca Citizen Security Council (CSC) was created in December 2002. This institution attached to the Municipality has the primary function of planning and coordinating in an articulated manner with the entities in charge of citizen security and developing public policies for the benefit of the Cuenca people. This drives the neighborhood organization to achieve a concept of mutual aid. The CSC works jointly with the Government of Azuay, the Ministry of Public Health, the Fire Department,

among others. The SIS ECU 911system has high technology and has a video-surveillance system and monitoring of events in the city in real time. Specifically, an intelligent video surveillance system was implemented in the historic center of the city, where there are more than 600 security cameras connected to SIS ECU 911 to monitor vehicular and pedestrian traffic, as well as to prevent crime and guarantee the safety of citizens and tourists. This modern equipment has video analytics such as face detection, loitering patterns, license plate detection and a loudspeaker system for immediate alert [42].

Citizen Participation

Cuenca has various forms of citizen participation that seek to involve the population in decision-making of the city planning. One of the main forms of citizen participation is through the Citizen Participation Boards, which are neighborhood organizations created to encourage citizen participation in local management. Another form of citizen participation in Cuenca is through the Consultative Councils, which are forums for dialogue between the municipality and different sectors of society, such as business, academics, and the community. These councils aim to encourage collaboration between society and local authorities to improve city management. For this, there are digital platforms for citizen participation, such as the virtual platform for citizen complaints, which allows citizens to report problems in their area. Another platform is "Cuenca Participa", which aims to promote citizen participation in decision-making [43]. In the same way, a digital platform has been developed to improve the management of public services such as water and garbage collection. Through this platform, citizens can make requests and report problems more efficiently, which has improved efficiency and transparency in service management.

Competencies

The planning model of Cuenca has different actors that play fundamental roles in the collection, management, administration and analysis of data in the city, which are presented in Fig. 3.

Each of these actors play important and fundamental roles that are clearly specified in the Annual Development Plan of the of Cuenca city. In this sense Cuenca Municipality is the actor that coordinates and plans the different operations in the city. Below is a summary of the powers and functions of each Institution (Table 1).

Discussion

Urban planning in Cuenca is an important and relevant issue for the development of the city. The city has a Develop Plan that focuses on improving the quality of life of the inhabitants and promoting the sustainable development of the city. The plan establishes a series of objectives and long-term goals. It also defines the strategies and actions necessary to achieve them. Among the main objectives of the plan are: Promote the protection of the cultural and natural heritage of the city, improving accessibility and urban mobility, by promoting public transport and promoting the use of bicycles and the tram.

Within its planning, the creation of an integrated public transport system has been established, which allows the mobility of citizens in an efficient and sustainable manner, promoting the development of tourist and cultural projects. That is, urban planning in

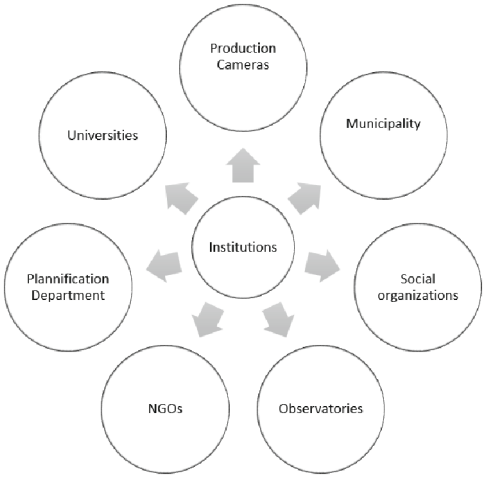

Fig. 3. Institutions of the data driven sustainable smart city in Cuenca

Table 1. Competences and Functions of Institutions

Competences	Functions
Planning Department	Participating in the process of formulating Cuenca Development Plan Making use of data to guide urban planning Using data, identifying patters and solving problems
Universities	Designing sustainable projects for the city and then presenting them to the Municipality. Ex. Design and implement the Monitoring, Follow-up and Evaluation System (SME) of Development programs and projects Offering educational programs of big data
Production Cameras	Finance development and sustainability projects
Observatories	Preparing periodic special reports on the progress in the objectives and goals of the Development plan. Ex. The Territorial Development Observatory (ODET) aims to observe and monitor the quality of life of the population Facilitating the evaluation of the actions undertaken within the city
NGOs	Providing technical, methodological and operational tools and regulations for the identification, prioritization, execution and coordinated evaluation of plans, programs and projects. Ex. Institute for Transportation & Development Policy Integrating resources and expertise through collective intelligence
Social organizations	Participating in decision-making, seeking the concretion of spaces for permanent dialogue between institutional actors and citizens in order to strengthen cantonal participatory democracy. Ex. Cuenca participa

the city focuses on the sustainable development of the city, the protection of cultural and natural heritage, the improvement of the quality of life of the inhabitants and the promotion of economic development. Planning and management is carried out jointly between the local, private camera, universities, observatories and social organizations. Decision-making and definition of strategies is articulated in a participatory manner, with horizontal relationships, despite the existence of a hierarchical position between society and local government and that the public administration bodies have the power to execute the resolutions. However, the framework of data driven sustainable smart city that was inspired in cities such us Barcelona and London, has different characteristics of Cuenca city, for example Cuenca has centralized its development plan in its Municipality through its public enterprises that play critical roles specially in the mobility, delivery of public services and sustainability projects. Moreover, the Planning Department is the one that coordinate the activities with the rest of the institutions. In the case of sustainable projects, universities and NGOS are the one that design sustainable projects and specific programs about new technologies. On the other hand, social organization, and observatories participate in the decision-making process in the city.

5 Conclusion

The rapid urban growth of cities generates the need to seek more sustainable and habitable cities and technology leads the way to build them. Thanks to digitization, the elements that make up these urban centers can be connected to each other and improve the well-being of millions of people. That is why a Smart City is one of the best options since it is characterized by taking advantage of the full potential of Information and Communication Technologies to create healthier, safer, more efficient and inclusive spaces. In these urban spaces, the connectivity of the devices is of great importance since it allows communication between them and the emission and reception of data. This information is ordered, classified and analyzed thanks to Big Data, which is capable of studying large volumes of data in real time to obtain trends and anticipate solutions, so that those responsible for the services can make the right decisions. This is where the term data driven smart city appears, which together with the need to make cities more sustainable become and data driven sustainable smart cities, which are cities that use ICTs to collect information through big data to then make decisions to achieve a more sustainable city. Although there is still no extensive literature on the data sustainable smart cities, a theoretical framework has been established for this type of cities that includes technology that include infrastructure, applications and data sources which depending on the progress of this, produces different operations and strategies to be developed in a city. Another dimension is the competencies that are abilities that various institutions have within a smart city to process, classify and analyze the information which projects and actions are created to achieve sustainability, equity and resilience in a city. As established in the objective of the research, it was sought to identify the potential of the city of Cuenca that fit into this framework since it is considered as a smart city that uses technological infrastructure with the skills of the different actors involved to apply sustainable projects. Among the initiatives that the city has applied are the use of sensors to monitor traffic, air quality and noise, the implementation of smart lighting systems

and the creation of a digital platform to improve the management of public services such as water and garbage collection. However, despite the fact that much progress has been made with the implementation of ICTs, this city has a very different context from cities like Barcelona and London, which were the cities that inspired the theoretical framework used. It is important to mention that to achieve the sustainability of a city, it depends to a great extent on the national and local contexts, especially with its public policies, the level of technological infrastructure installed, and the skills developed by the institutions involved. However, there are still many gaps in this topic of data driven sustainable smart cities, such as identifying whether other cities in the country can adapt to the theoretical framework used, as well as identifying opportunities and challenges to develop data driven smart sustainable cities, the public policies necessary to promote this type of cities among other topics that could be explored in future researches.

References

1. Battista, G., Evangelisti, L., Guattari, C., Basilicata, C., Lieto Vollaro, R.: Buildings energy efficiency: interventions analysis under a smart cities approach. Sustainability **6**(8), 4694–4705 (2014). https://doi.org/10.3390/su6084694
2. Batty, M.: Smart cities, big data. Environ. Plann. B. Plann. Des. **39**(2), 191–193 (2012). https://doi.org/10.1068/b3902ed
3. Batty, M.: Big data, smart cities and city planning. Dial. Hum. Geogr. **3**(3), 274–279 (2013). https://doi.org/10.1177/2043820613513390
4. Bibri, S.E.: Data-driven smart sustainable cities of the future: an evidence synthesis approach to a comprehensive state-of-the-art literature review. Sustain. Fut. **3**(100047), 1–23 (2021). https://doi.org/10.1016/j.sftr.2021.100047
5. Bibri, S.E., Krogstie, J.: The emerging data–driven Smart City and its innovative applied solutions for sustainability: the cases of London and Barcelona. Energy Inf. **3**(1), 1–42 (2020). https://doi.org/10.1186/s42162-020-00108-6
6. Bici Publica Cuenca. (Bici Publica Cuenca) Recuperado el 1 de April de 2023 (2022). https://www.bicicuenca.com/
7. CAF. (CAF) Recuperado el 1 de April de 2023. https://www.caf.com/es/conocimiento/visiones/2020/06/brasil-lider-govtech-de-america-latina/
8. Calzada, I., Cowie, P.: Beyond smart and data-driven city-regions? Rethinking stakeholder-helixes strategies. Reg. Maga. **308**(4), 25–28 (2017). https://doi.org/10.1080/13673882.2017.11958675
9. Center by International Government Innovation. (Center by International Government Innovation) Recuperado el 1 de April de 2023 (2018). https://www.cigionline.org/articles/smart-cities-need-local-democracy/?utm_source=google_ads&utm_medium=grant&gclid=CjwKCAjwitShBhA6EiwAq3RqA291LySBNhtgsWJXnBvmbgy_FxMuv_Nx39EEbkK55y9poIL4Iu0qMRoCPIoQAvD_BwE
10. CEPAL. (CEPAL) Recuperado el 1 de April de 2023 (2022). https://repositorio.cepal.org/bitstream/handle/11362/48000/1/S2200488_es.pdf
11. Copaja, M., Esponda, C.: Tecnología e innovación hacia la ciudad inteligente. Avances, perspectivas y desafíos. Bitacora Urbano Territorial **29**(2) (2019). https://doi.org/10.15446/bitacora.v29n2.68333
12. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://www.cuenca.gob.ec/content/cuenca-la-mejor-puntuada-en-el-pais-como-ciudad-inteligente-y-sostenible

13. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://www.cuenca.gob.ec/content/inicia-plan-piloto-de-electromovilidad-en-cuenca
14. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://www.cuenca.gob.ec/content/drones-monitorean-la-circulaci%C3%B3n-vehicular-en-cuenca
15. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://www.cuenca.gob.ec/sites/default/files/planificacion/dic2022/2_1_Diagnostico.pdf
16. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://www.cuenca.gob.ec/content/alcald%C3%ADa-de-cuenca-present%C3%B3-mapa-de-ruido-y-gu%C3%ADas-did%C3%A1cticas
17. Cuenca Municipality. (Cuenca Municipality) Recuperado el 1 de April de 2023 (2022). https://cuencaparticipa.cuenca.gob.ec/?locale=es
18. de la Harpe, A., Thurner, T.W.: The critical role of information system integration in a horizontal merger. J. Cases Inf. Technol. (JCIT) **21**(4), 1–13 (2019)
19. El Comercio. (El Comercio) Recuperado el 1 de April de 2023 (2023). https://elmercurio.com.ec/2023/01/20/cuenca-ciudad-inteligente-sostenible-2022/
20. Future Space. (Future Space) Recuperado el 1 de April de 2023. https://www.futurespace.es/uso-ia-smart-cities-para-eficiencia-energetica-y-sostenibilidad/
21. Guarda, T.I., Oliveira, P., Ribeiro, M.I., Fernandes, A.J.: How to measure the performance of a smart city. In: CAIW 2020: Workshops at the Third International Conference on Applied Informatics 2020, vol. 2714, pp. 77–86. CEUR Workshop Proceedings, Ota (2020). https://ceur-ws.org/Vol-2714/icaiw_aiesd_5.pdf
22. Guarda, T., Fernandes, C., Augusto, M.F.: Technology, Business, Innovation, and Entrepreneurship in Industry 4.0. Springer, Cham (2023). https://doi.org/10.1007/978-3-031-17960-0
23. Guarda, T., et al.: Internet of Things challenges. In: IEE (ed.) 12th Iberian Conference on Information Systems and Technologies (CISTI), pp. 1–4. IEEE (2017). https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7975936&casa_token=X1wQ9Y2C_pgAAAAA:dMCNRggeTj9DJ9IZoY1Wzy1w40NuKutNtVpNzyk4igHfKH5wnwcSa1-6fzWNeSigXBkki8Nhggw&tag=1
24. Happle, G., Wilhelm, E., Fonseca, J.A., Schlueter, A.: Determining air-conditioning usage patterns in Singapore from distributed, portable sensors. Energy Procedia **122**, 313–318 (2017). https://doi.org/10.1016/j.egypro.2017.07.328
25. Hashem, I.A., et al.: The role of big data in smart city. Int. J. Inf. Manag. **36**(5), 748–758 (2016). https://eprints.soton.ac.uk/394830/1/IJIM_Big_Data_in_Smart_City_Final.pdf
26. Ismagilova, E., Hughes, L., Rana, N.P., Dwivedi, Y.K.: Security, privacy and risks within smart cities: literature review and development of a smart city interaction framework. Inf. Syst. Front. **24**, 1–22 (2020). https://doi.org/10.1007/s10796-020-10044-1
27. ITU WRC. (ITU) Recuperado el 1 de abril de 2023 (2021). https://www.itu.int/es/mediacentre/backgrounders/Pages/smart-sustainable-cities.aspx
28. Lacinák, M., Ristvej, J.: Smart city, safety and security. Procedia Eng. **192**, 522–527 (2017). https://doi.org/10.1016/j.proeng.2017.06.090
29. Laufs, J., Borrion, H., Bradford, B.: Security and the smart city: a systematic review. Sustain. Cities Soc. **55**, 102023 (2020). https://doi.org/10.1016/j.scs.2020.102023
30. Lopes, I.M., Guarda, T.: The relationship between smart cities and the internet of things in low density regions. In: Antipova, T., Rocha, A. (eds.) DSIC18 2018. AISC, vol. 850, pp. 369–378. Springer, Cham (2019). https://doi.org/10.1007/978-3-030-02351-5_42
31. Martins, F., Patrão, C., Moura, P., Almeida, A.T.: A review of energy modeling tools for energy efficiency in smart cities. Smart Cities **4**(4), 1420–1436 (2021). https://doi.org/10.3390/smartcities4040075

32. United Nations. Recuperado el 1 de April de 2023. https://www.un.org/es/impacto-acad%C3%A9mico/page/sostenibilidad#:~:text=En%201987%2C%20la%20Comisi%C3%B3n%20Brundtland,de%20satisfacer%20sus%20necesidades%20propias
33. Pal, D., Triyason, T., Padungweang, P.: Big data in smart-cities: current research and challenges. Indon. J. Electr. Eng. Inf. (IJEEI) **6**(4), 351–360 (2018). https://doi.org/10.11591/ijeei.v6i1.543
34. Pedrotti, A.: Portal Movilidad España. (Portal Movilidad España) Recuperado el 1 de April de 2023 (2022). https://portalmovilidad.com/si-a-los-buses-electricos-en-espana-los-operadores-y-ciudades-con-los-planes-mas-ambiciosos/
35. Portal Diverso. Portal Diverso. (Portal Diverso) Recuperado el 1 de April de 2023 (2022). https://portaldiverso.com/los-controles-de-seguridad-en-cuenca-y-la-provincia-dan-buenos-resultados/
36. Radu, L.D.: Disruptive technologies in smart cities: a survey on current trends and challenges. Smart Cities **3**(3), 1022–1038 (2020). https://doi.org/10.3390/smartcities3030051
37. Ruggieri, R., Ruggeri, M., Vinci, G., Poponi, S.: Electric mobility in a smart city: European overview. Energies **14**(2), 315 (2021). https://doi.org/10.3390/en14020315
38. SER. (SER) Recuperado el 1 de April de 2023 (2020). https://cadenaser.com/emisora/2020/08/06/ser_cuenca/1596714103_942271.html
39. Telefónica, F.: Smart Cities: un primer paso hacia la internet de las cosas. Fundación Telefónica (2011)
40. The Copenhagen Centre on Energy Efficiency. (The Copenhagen Centre on Energy Efficiency) Recuperado el 1 de April de 2023. https://c2e2.unepccc.org/kms_object/oslo-norways-street-lighting-retrofit/
41. Toli, A.M., Murtagh, N.: The concept of sustainability in smart city definitions. Front. Built Environ. **6**(77) (2020). https://doi.org/10.3389/fbuil.2020.00077
42. United Nations. (United Nations) Recuperado el 1 de April de 2023/ https://www.un.org/sustainabledevelopment/es/cities/
43. Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M.: Internet of things for smart cities. IEEE Internet Things J. **1**(1), 22–32 (2014). https://doi.org/10.1109/JIOT.2014.2306328