

Smart Cities and the Implementation of Artificial Intelligence in Autonomous Transportation – A Proposal for the City of Querétaro

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— Abstract—

Smart cities, powered by the use of artificial intelligence (AI), represent an innovative approach to addressing contemporary urban challenges and improving the residents' quality of life. These cities use advanced technologies and data analysis to optimize resource management, public services, mobility, and decision-making. This article compares different aspects of urban life, such as autonomous transportation, application of renewable energy, use of the Internet and level of foreign direct investments in the cities of Tokyo, Singapore and Querétaro to finally give a proposal for the implementation of autonomous buses in the city of Querétaro, using the good practices applied in Tokyo and Singapore.

Keywords:

Smart cities; IoT; autonomous transportation.

Due to the rapid growth of population density in urban cities, infrastructure and services are required to meet the needs of city residents. On this basis, there is a significant increase in digital devices, such as sensors, actuators, and smartphones, that drive huge business potential for IoT (Internet of Things), as all devices can interconnect and communicate with each other on the Internet. The IoT prototype is composed of smart, self-adjustable objects that are connected to each other through a global network infrastructure. The IoT is mostly considered as real objects, widely dispersed, with low storage and processing capacity, with the aim of improving the reliability, performance, and security of the smart city and its infrastructures.

The Internet of Things is an infrastructure that includes physical devices, modern vehicles, buildings, and even essential electrical devices that we use constantly, interconnected with each other over the Internet so that they can accumulate and exchange data with each other. These "Things" have priority and the ability to self-organize and communicate with other things without human intervention. The IoT concept aims to present an even more ubiquitous and immersive Internet. In addition, by allowing easy access and interaction with a wide variety of devices, such as appliances, monitoring, surveillance cameras, sensors, displays, actuators, and vehicles. The IoT will improve the development of various applications that take advantage of the enormous amount and diversity of data produced by objects to implement more services to companies, citizens, and public administrations (Yang, Han, Wang, Jiang, Song, 2020).

Increasingly, organizations in various industries are using IoT to operate more efficiently, provide better customer service, improve decision making, and increase business value. With IoT, data can be transferred over a network without the need for person-to-person or person-to-computer interactions. An IoT ecosystem consists of web-enabled smart devices that use embedded systems (such as processors, sensors, and communication hardware) to collect, send, and act on the data they acquire from their environments. IoT can also use artificial intelligence and machine learning to help make data collection processes easier and more dynamic.

IoT allows machines to complete tedious tasks without human intervention. Companies can automate processes, reduce labor costs, reduce waste, and improve service delivery. IoT helps make it less expensive to manufacture and deliver goods and provides transparency into customer transactions. IoT is one of the most important technologies and continues to advance as more companies realize the potential of connected devices to stay competitive (Gillis, 2023).

IoT offers several benefits to organizations. Some benefits are industry-specific, and others are applicable across multiple industries. Common benefits for businesses include the following:

- Oversees general business processes.
- Improve Customer Experience
- Save time and money.
- Improves employee productivity.
- Provides integration and adaptive business models.
- Enables better business decisions.
- Generate more revenue.

There are numerous real-world applications of the Internet of Things, ranging from consumer IoT and enterprise IoT to manufacturing IoT. IoT applications span numerous verticals, including automotive, telecommunications, and energy. In the consumer segment, for example, smart homes equipped with smart thermostats, smart appliances, and connected electronics, lighting, and heating devices can be controlled remotely via computers and smartphones (Evans, 2011).

IoT can be implemented very well in the concept of smart cities.

A smart city is a municipality that uses information and communication technologies (ICTs) to increase operational efficiency, share information with the public, and improve both the quality of government services and the well-being of citizens. The overall mission of a smart city is to optimize city functions and drive economic growth while improving the quality of life for its citizens using smart technology and data analytics. The smart city is given value based on what they choose to do with the technology, not just how much technology they may have. Several important characteristics are used to determine the intelligence of a city. Some of these characteristics are:

- An infrastructure based on technology
- environmental initiatives :
- a high-performance public transport system
- a safe sense of urban planning and
- to live and work within the city and use its resources

The success of a smart city depends on its ability to form a strong relationship between the government and the private sector. This relationship is necessary because most of the work that goes into creating and maintaining a data-driven digital environment occurs outside of government (Rodriguez & Lopez, 2018).



Note. Adapted from <https://www.techtarget.com>, 2023.

Figure 1. Components of a Smart City

Smart cities use a combination of Internet of Things (IoT) devices, software solutions, user interfaces (UIs), and communication networks. However, they rely primarily on the IoT. IoT devices sometimes have processing capabilities called edge computing. Perimeter computing ensures that only the most important and relevant information is communicated through the communication network. A firewall security system is also necessary for the protection, monitoring, and control of network traffic within a computer system (Rodríguez & Lopez, 2018).

Conservation and energy efficiency are important parts of smart cities. Smart cities use their network of connected IoT devices and other technologies to achieve their goals of improving the quality of life and achieving economic growth. Successful smart cities follow four steps:

1. Collection: Smart sensors throughout the city collect data in real time.
2. Analysis: The data collected by the smart sensors is evaluated to extract meaningful information.
3. Communication: The knowledge found in the analysis phase is communicated to decision-makers through strong communication networks.
4. Action: cities use insights gleaned from data to create solutions, optimize operations and asset management, and improve residents' quality of life.

Sustainability is another important facet of smart cities. Urbanization is expected to increase further in the coming years. According to a United

Nations report, about 55% of the world's population now resides in an urban area or city. This figure is expected to increase by 68% in the coming decades. Smart technology will help cities sustain growth and improve efficiency for the well-being of citizens and governmental efficiency in urban areas in the coming years. While cities already have environmental advantages, such as smaller geographic footprints that impact fewer ecological systems, they also negatively impact the environment with emissions, such as their extreme use of fossil fuels.

Many cities around the world have begun to implement smart technologies, and some stand out as the most advanced in development. Such as the following cities: Kansas City, Missouri, USA; San Diego, California, USA; New York, New York, USA; Toronto, Canada; Singapore, Tokyo, Japan; and many more (Smith, 2020).

Most new smart city projects are concentrated in the Middle East and China, but in 2018, Reykjavik and Toronto were listed alongside Tokyo and Singapore as some of the smartest cities in the world. The city-state of Singapore, often considered the gold standard of smart cities, uses IoT-enabled sensors and cameras to monitor the cleanliness of public spaces, the density of crowds, and the movement of locally registered vehicles. Its smart technologies help businesses and residents monitor energy use, waste production, and water use in real time. Singapore is also testing autonomous vehicles, including full-size robotic buses, as well as a senior tracking system to ensure the health and well-being of its senior citizens (García & Pérez, 2019).

METHOD

The methodology used in this article is qualitative and quantitative statistical analysis, providing and guaranteeing both safety and accuracy to the research results. This article makes use of a statistical graph of progressive growth for the representation of the percentage of different indicators. The graphs presented are comparative statistics and show the quantitative data of the advancement of technology in smart cities, making a comparison between Querétaro, Singapore, and Tokyo. The statistical data collected are from secondary sources, using as sources government institutions and the statistical institutes of the aforementioned countries to collect the data necessary for the creation of the graphs. Descriptive statistics are used in the quantitative methodology part to analyze the sources and the data obtained.

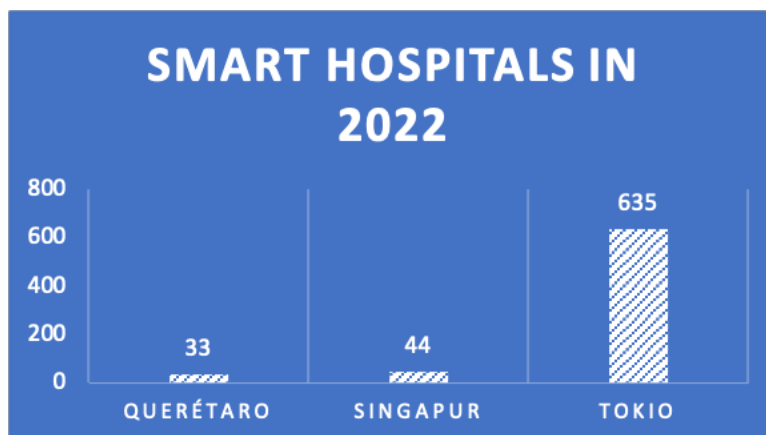
RESULTS

In Singapore and Tokyo, being two developed smart cities, an artificial intelligence system has been implemented in many aspects of public welfare. However,

Querétaro also has several advances in the areas of transportation, renewable energies, and penetration of international capital through foreign companies.

Table 1
Smart hospitals in 2022

Querétaro	Singapur	Tokio
33	44	635

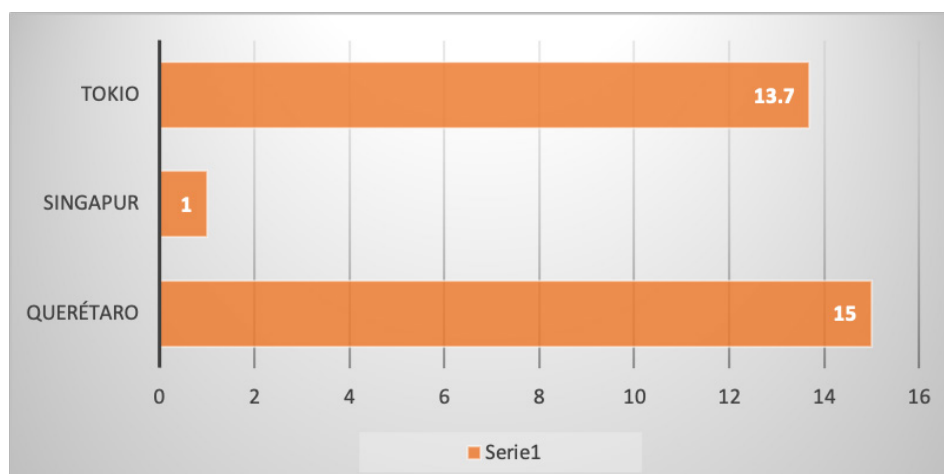


Note. Own elaboration.

In the first table, we observe the differences in the health sector. In Querétaro, it has recently been one of the sectors that has had the most development, especially private hospitals that are constantly growing. Currently, the city has 25 private hospitals with artificial intelligence and 8 public hospitals. In Singapore, there are 16 public hospitals, 8 private hospitals, and 20 public polyclinics. In Tokyo, the number of these health centers is significantly higher, 635 in total.

Tabla 2*Uso de Energía renovable en % para 2022*

Querétaro	Singapur	Tokio
15	1	13.7

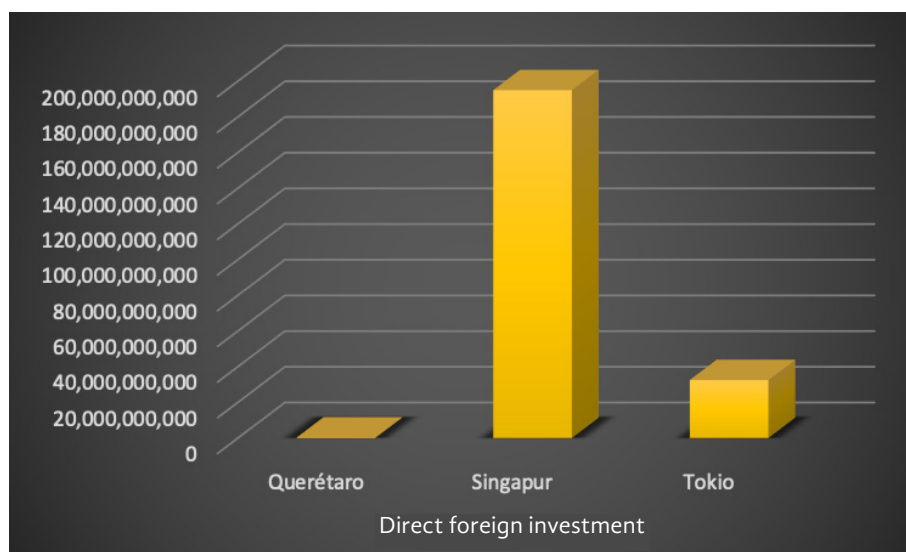


Note. Own elaboration.

Table No.2 evaluates the use of renewable energy in the three cities. Querétaro is the city where different renewable energies, such as wind, hydro, and biomass, have been implemented the most. Singapore, for lack of natural resources, hardly uses green energy, and Tokyo has many government policies that promote the use of this type of energy.

Table 3
Foreign direct investment in 2022, amount in USD

Querétaro	Singapur	Tokio
380,000,000	195,000,000,000	32,530,000,000

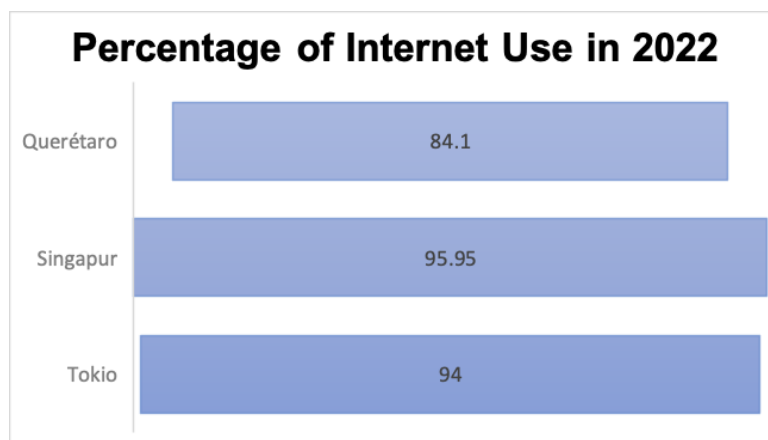


Note. Own elaboration.

The third table shows the different foreign investments through international companies in the three cities. Singapore is the leader in this indicator, and Querétaro, although every year more international companies of different branches open in the city, still does not reach high levels of foreign capital.

Table 4
Internet usage in % by 2022

Querétaro	Singapur	Tokio
84.1	95.95	94



Note. Own elaboration.

In the last table, No.4, we observe the difference in the use of the internet and smart devices in the three cities. Tokyo and Singapore have almost similar levels, with almost total reach of the population, using new technologies. Querétaro has also made great progress in this indicator, reaching 84% by the end of 2022.

All these data show the advancement of technology in the different areas of the societies studied - transportation, investments, health, etc., which allows rapid progress towards making Tokyo and Singapore, in this case, increasingly smarter cities. Querétaro is also following in their footsteps by implementing more and more tools appropriate to a smart city. For such purposes, the authors give a project proposal for autonomous buses that could be incorporated into the city of Queretaro and thus increase the use of intelligent technology and artificial intelligence.

DISCUSSION AND CONCLUSION

Proposal for an autonomous bus project in the city of Queretaro

With the information on the application of artificial intelligence and its use in different aspects of human life in smart cities, it can be demonstrated that it has great advantages for the growth and development of cities today. One of these aspects is also in the area of transportation, where more and more autonomous vehicles are helping to improve traffic flow in cities and

prevent accidents. An example of this is the use of autonomous transportation. In France, the city of Lille introduced the autonomous metro in the 1980s. Today, there are also autonomous buses in France, Scotland, Spain, and many other countries. In the European Union, since 2022, there are laws that require public transport to have artificial intelligence to protect pedestrians. Artificial intelligence opportunities in transportation also include logistics optimization through real-time and historical data, vehicle maintenance prediction, supply chain optimization, and route planning with traffic prediction and real-time updates.

Tools to implement:

- The Blind Spot Detection (BSD) system is a solution oriented to large vehicles, whose field of vision may be more limited. It detects pedestrians, cyclists, and other moving objects in real time, within the vehicle's reduced visibility zones, through image processing with advanced artificial intelligence. When the person or object moves within the vehicle's safety zone, the system sends a visual and acoustic signal to the driver, alerting them to the presence of an object in the blind spot.
- The Driver Status Monitor (DSM) has a large number of applications. Artificial intelligence detects distractions on the part of the driver, for example, if someone is smoking, using the phone, or showing signs of drowsiness. This solution, in addition to monitoring and recording distraction signals, alerts the driver to the incident by activating an acoustic and light alarm. These incidents are recorded on a server for later evaluation.
- The Azimuth 360 system works with a series of cameras placed around the vehicle. Each of these cameras collects a large amount of information that is transmitted to the driver in near real time, giving him or her a peripheral view of what is happening around the vehicle. The system is a great help when driving in the dark (thanks to its night vision), greatly facilitates maneuvering, and helps to avoid collisions.
- Use of a tool capable of storing and managing all the information generated by these security systems. When an incident occurs, it is important to have an analysis of where, when, and under what circumstances the event occurs. The Azimut BusBrain management platform allows you to visualize, in real time, each of the vehicles in the fleet, see its location, know how fast it is traveling, know what is happening inside and outside the vehicle, as well as the incidents that have occurred in that vehicle.

In this article, the authors make the proposal to create a network of autonomous buses that, through artificial intelligence, would cause an improvement in the circulation of vehicles in the State of Queretaro. Part of the artificial intelligence to be implemented in the buses of Queretaro would be the Azimut 360 system, that puts cameras around the vehicle collecting information in real time. The proposal itself consists of creating autonomous transportation routes that run along the busiest avenues of the city, which are Avenida 5 de Febrero and part of the Historic Center of the city, to reach the bus terminal at the other end. The line would be complementary to the existing public transportation system and would use an exclusive lane for better accident prevention. The proposal would be made to the municipality of Querétaro to make the autonomous bus part of its fleet. Based on calculations made from the beginning of the implementation of autonomous buses in Tokyo and Singapore, and adjusted to the city of Queretaro, traffic would decrease by 10-15% thanks to the use of the route, and would prevent at least 10% of road accidents involving pedestrians.

Smart cities have been a great achievement of mankind that has helped improve human life in many parts of the world, thanks to artificial intelligence. Several areas of the cities and the life of each individual have changed a lot with its implementation. In conclusion, Artificial Intelligence is playing an increasingly important role in transportation, driving optimization, efficiency, and profitability in logistics operations. From route optimization and fleet management to real-time tracking and improved safety, AI offers innovative solutions to transportation challenges. The other areas mentioned in this article, such as renewable energy, internet usage, and international business, have also been greatly improved by the use of artificial intelligence, turning cities into *Smart cities* in more and more places around the world. Artificial intelligence has its advantages, but also has clear disadvantages of its use, such as job displacement, privacy and security issues, and technological dependence. However, it has been proven that its increased use in human life has greatly improved it compared to past decades and is expected to continue to increase opportunities for development and welfare in the coming years.

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