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Revisión Sistematica de Tecnogías de IoT para el desarrollo de un sistema de información en transporte público

Systematic review of IoT technologies for development of an information system in public transport

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Resumen
La computación en la nube y el Internet de las Cosas (IoT) como soporte tecnológico para la construcción de Sistemas de Información Geográfica (SIG) están cambiando la forma en que se desarrollan y despliegan estos sistemas. La infraestructura tecnológica como plataforma de despliegue permite que SIG aproveche sus altas capacidades de almacenamiento y procesamiento, mientras que el uso de dispositivos IoT permite la automatización del proceso de recolección de datos. El objetivo de este trabajo es recopilar información relevante sobre estas tecnologías, compararlas y analizarlas, a través de la revisión sistemática de literatura (SLR) estos objetivos se lograron con el estudio del tema central del IoT, realizando filtros de búsqueda para la recopilación de información de acuerdo a lo más relevante encontrado al análisis metódico, los resultados abarcaron preguntas significativas con sus respectivas respuestas, y análisis de las diferentes tecnologías que abarcan, simuladores sobre tránsito vehicular, proyectos.

Palabras Clave: SIG, IoT, Geolocalización, Sistemas de Información, Rastreo.

Abstract

Cloud computing and the Internet of Things (IoT) as technological support for the construction of Geographic Information Systems (GIS) are changing how these systems are developed and deployed. The technological infrastructure as a deployment platform allows GIS to take advantage of its high storage and processing capabilities, while the use of IoT devices allows the automation of the data collection process. The objective of this work is to collect relevant information about these technologies, compare them, and analyze them, through the systematic literature review (SLR) these objectives were achieved with the study of the central theme of the IoT, performing search filters for the collection of information according to the most relevant found to the previous methodical analysis, the results covered significant questions with their respective answers, and analysis of the different technologies that they cover, simulators about vehicular traffic, projects that use different IoT tools in such a way that the necessary hardware and software elements be determined when designing a bus route information system.

Keywords: *GIS, IoT, Geolocation, Information Systems, Tracking.*

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INTRODUCTION

Over time, technology has taken over many aspects of our daily lives, from automated vehicles with more sensors and electronics, to a whole range of smart home appliances. This new trend makes it increasingly desirable to have greater control over these devices, whether it is to display more information about their status or to control them remotely (Gándara, 2020).

Currently, many countries have been developing communication platforms, which have allowed users to access different services with the use of mobile applications. Seeing the state of traffic in the city, doing the 'check in' before a flight, planning an exercise routine, and managing personal finances are situations that could have been in futuristic books, but today they are real facts, and the applications constitute a phenomenon that generates a new technological ecosystem, with the culture of the digital in between. The services are almost infinite and all segments of the population can access them through a mobile device, such as a phone or a tablet.

Countries like Korea, Norway, and Switzerland are the ones with the most "devices" connected to the internet, according to data from the Organization for Economic Cooperation and Development (OECD). For example, "In Korea, the number of online devices per 100 people is almost 40 devices. In Denmark, there are 32.7 devices connected to the internet for every hundred inhabitants. Switzerland, further away, has 29 devices connected for every 100 inhabitants". A little further, the United States and the Netherlands appear with 24 devices each (S.A., 2016).

The use of technologies has a positive impact on cities, which over time create ways to improve daily life, well-being, and facilities. In addition, these technologies allow us to improve and automate processes and obtain positive results in our quality of life (González & Gutiérrez, 2017). Technology must be understood as a tool. That is why we must always emphasize that a smart city must be a sustainable city and not just a technological one.

The technologies involved in the Internet of Things (IoT) have emerged intending to create sustainable cities, whether economically, socially, or environmentally. Information and communication technologies (ICT) are applied in these to provide them with infrastructures that guarantee: sustainable development, an increase in the quality of life of citizens, and greater efficiency of available resources. Active citizen participation (Endesa, 2021).

Among the network technologies used, WLANs continue to be one of the most used to connect devices to the network, with the 802.11 a/b/g/n/ac, 802.11.af, 802.11ah protocols with their security and mid-range signal. Then came the WNAM (Wireless Neighborhood Area Network) with an average range of 5 to 10 kilometers with its Wi-SUN and ZIG BEE-NAN protocols (Abawajy et al., 2021). The WWAN (Wireless Wide Area Network) has a long range of between 10 to 100 kilometers, within these wireless networks there are two different technologies, the first is cellular technologies that include 2G/3G/4G, LTE-MTC, 5G, and LPWAN (Low Power Area Wide Network), which are low power wide area networks. It should be noted that cellular networks, apart from having a higher energy consumption, are connected to telephone line operators that charge for the use of services used, either by call, message consumption or network. On the part of LPWAN, the technologies that stand out the most are SIGFOX and LORA due to their great deployment of sending information over great distances (Zemrane et al., 2019).

IoT technologies cover different scopes, infrastructures, and objectives different investigations and articles will be analyzed, breaking down the most used and important to select the best one for the implementation of the information system.

For the Internet of Things (IoT) to be possible, it is necessary to combine three factors. Devices objects such as vehicles, watches, televisions, mobile phones, among others. It is important that these devices have characteristics that allow communication with the other elements. For example: chips, Internet connection, antennas, sensors, etc. Net It is what allows a communication between one thing and the other. These means are WiFi, Bluetooth and 3G or 4G mobile data. Control system all the data that is captured through this communication must be processed, therefore, it is important to have a system to control each aspect and create new connections.

MATERIALS AND METHODS

In the present research work, a systematic literature review (SLR) (Zemrane et al., 2019) has been carried out to gather relevant information about IoT technologies, differences, implementations, previous studies, costs, applications, simulations, and problems that they try to solve, development methods, all this information to enrich knowledge and have the best search results through filters and chains with information to then carry out a study of inclusion and exclusion criteria to reduce the number of investigations found. These searches were carried out in different repositories of universities and higher education centers, extracting information from reliable and investigative sources. For the elaboration of the SLR, the following steps were applied:

1) Research questions were established.
2) The selected articles were analyzed.

Based on the first step, some research questions were established:

1) What is IoT and how does it work?
2) Which technologies encompass IoT?
3) What projects and IoT systems exists in public transport?
4) What methodologies are applied in mobile application development projects??
5) Which simulators are the most used for vehicular traffic?

In the second step, a search of the keywords was carried out, was carried out in the repositories of Google Scholar, this was done to control the literature and include and exclude the filtered information**.** Table 1 shows the articles found.

Table 1: Search String Results

Chain	Results
""Cloud Computing" + "Networking"	8970
" Cloud computing" + "Networks" + "IoT "	4830

" Cloud computing" + "Networks" +"IoT"+"Geolocation "	**23**
" Web Application" +"Mobile Application"	900
"Web Aplication"+MobileAplication"+"Servers"	321
Web Aplication+MobileAplication"+"Servers"+"Geolocation"	**30**
" Information Systems "+"IoT"	4230
" Information Systems "+"IoT"+"GoogleMaps"	326
Information Systems +"IoT"+"GoogleMaps"+"GPS" + "Open Street maps"	**7**
"Tracking systems "+" Arduino"	76
" Tracking systems "+"Arduino"+" vehiclemonitoring "	**12**
"Smart phone"+ "Web"	120000
"Smart phone"+ "Web"+"flutter"	359
Smart phone+ "Web"+"flutter"+"Encode"	**21**

Source: Authors

For the search of the results of the keywords, a generalized search of the atypical topics was carried out, adding a new chain to reduce the volume of search quantities found in the articles, these can be added by using "+" or with boolean operators "AND" and "OR" and that were established in the search strings most frequently.
Once the scope of the review has been established, defined a set of inclusion and exclusion criteria to selectthose works that are relevant when answering the defined research questions.

Inclusion Criteria

Based on the first step, some research questions were established:

1) Articles that have some implementation with IoT Technologies.
2) Software development articles that implement geolocation.
3) Articles that have obtained results similar to the development of the system to be implemented.
4) Articles that apply methodologies for the development of IoT systems.

Exclusion Criteria:

1) Articles that apply high-cost IoT technologies.
2) Articles that are not in English or Spanish.
3) Articles that are more than 7 years old.

For the elaboration of the search chain, a search of works related to the present investigation was carried out, once the most relevant ones were selected, the most repeated words were filtered, later the definition of combinations of terms was carried out, for the conformation of the most successful search string, resulting in 4 in total, of which the following was selected:
"Cloud Computing" + "Networking had a result of 8970 results adding to the search string "IoT"+"Geolocation" and a filter was applied that reduced a result to 23 results. A search for "Web application" + "Mobile application" was carried out with a result of 900 searches in which the filter was applied and new search strings were added such as

mobile "+" Servers "+" Geolocation" to reduce your search at 30. A search was carried out with the topics "Information Systems" + "IoT" with a result of 4230searches, adding new search strings "+" Google Maps "+" GPS " + "Open Street Maps" and filter gave a result of 7 articles. A search was carried out with the themes of "Arduino "+" tracking systems" with a result of 76 searches adding new search strings "Vehicle control" its result was reduced to 12 and finally asearch for "Smart phone" was carried out + "Web" resulting in a total of 120,000 results which applying the filter and adding new search strings Smartphone + "Web" + "flutter" + "Encode" gives a result of 21 results.
Now, the third part, relevant articles for the research were selected and analyzed. According to the point ofview and the analysis that we want to give to this article, which consists of reducing the large amounts of search to only focus on the most relcevant and important information based on the desired objectives.

RESULTS AND DISCUSSION

For the realization of this article, several studies were analyzed that break down different methods or technologies that study IoT applied in different projects, this information collection served as references to choose the main idea to develop the project of information systems and bus routes and select a technology that can be applied using the available resources and the required needs.
To answer the first research question, the basic and introductory concepts about IoT were investigated, which highlights the following: The Internet of Things IoT is the network of physical objects: devices, instruments, vehicles, buildings, and other elements embedded with electronics, circuits, software, sensors, and network connectivity that enables these objects to collect and exchange data. The Internet of Things allows objects to be remotely sensed and controlled over an existing network infrastructure, creating opportunities for more direct integration of the physical world into computing systems and resulting in greater efficiency and accuracy (Pradyumna Gokhale1, Omkar Bhat2, 2019).
For an IoT platform to be considered as an option within the development of this type of a product,it must be able to manage the information reliably, this means that it must collect the information sent by the device, store and/or analyze the information, represent or expose the information in such a way that the user can make use of it. The security of the system must be guaranteed, so as not to expose the data to anyone who has not been previously authorized (JACOBSON, 2017).
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IoT works through identification which are devices that can communicate with each other, there are different identifiers or identification schemes within the IoT. Identifiers can be categorized as: Object Identifier, Communication Identifier, and Application Identifier.

- Object identifiers represent physical or virtual objects within an IoT system, an example of this type of identifier is the barcode or the RFID card.
- Communication identifiers identify nodes in a network that have communication capabilities, that is, that have the ability to exchange data. The most widespread communication identifier is the IP address.
- Application identifiers identify the different service layers provided by the different applications that coexist in an IoT system.

The protocol: it is the way in which the different devices in an IoT system communicate in the distance can be very varied, although the most widespread, and by far, is wireless communication, with protocols based on wireless technologies being the most used. Considering the scope of communication, a distinction must be made between short, medium and long distance:

- Short distance: in this range the most used protocol is Bluetooth, although if faster data transmission is required, the most used is UWB (Ultra-Wideband).
- Medium distance: in this range the most widespread protocol is Wi-Fi (with its different 802.11 standards), although the ZigBee protocol is becoming more and more widespread, which implies the use of simpler hardware by the devices.
- Long distance: in this range the most used is 5G, although if the necessary data rate is very low (areas with little coverage) the LPWAN protocol (Low-Power Wide-Area Networking) is very widespread.

To answer the second research question, a search was carried out on the most used IoT technologies today and what are the ranges of scope that can be reached. Sigfox is a French network operator that has deployedan IoT network based on LP WAN technology and that uses the free band of 868 MHz in Europe and 915 MHz in the United States. This technology allows very little information to be sent over long distances withvery low energy use and to be independent of telephony deployments. Among the solutions and companies that offer alternative connectivity solutions to the classic GSM/3G/4G. Each node can cover a fairly large coverage area. In addition, companies that need to improve coverage in their area can install a repeater equipment (Vejlgaard et al., 2017).

LoRa and LoraWAN are capable of transmitting over very long distances, it was determined that LoRaWAN should support a star topology. Nodes transmit directly to a gateway that is powered and connected to a backbone infrastructure. Gateways are powerful devices with powerful radios capable of receiving and decoding multiple simultaneous transmissions up to 50. Three classes of node devices are defined: Class A end devices: the node transmits to the gateway when necessary. After transmission, the node opens a receive window to get queued messages from the gateway. Class B end devices with scheduled receive slots: the node behaves like a Class A node with additional receives windows at scheduled times. Gateway beacons are used for the time synchronization of end devices (Zorbas & O'Flynn, 2019).

LPWAN is gaining popularity in the industry and research communities due to its low power, long range, and low-cost communication features. It provides a long communication range of 10 to 40 km in rural areas and 1 to 5 km in urban areas. These promising aspects of LPWAN have prompted recent experimental studies on LPWAN performance in outdoor and indoor environments. In short, LPWAN is very suitable for IoT applications. They only need to transmit small amounts of data in the long run (Peña Queralta et al., 2019).

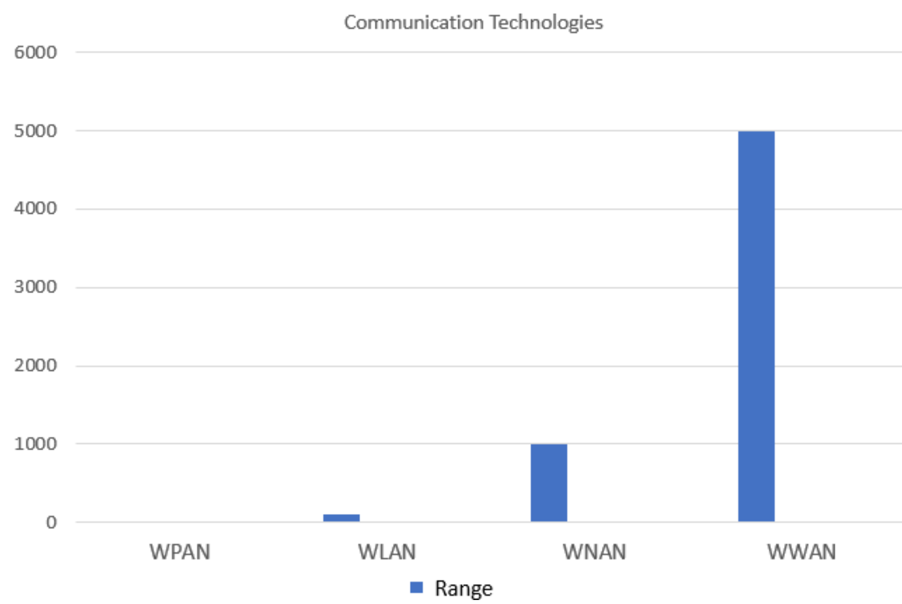

Figure 1: Distances between communication technologiesSource: Authors

The ranges of the different information technologies are shown in figure 1, the different distances that these technologies can reach, taking into account that WPAN (Wireless Personal Area Network) has a range of 10 to 100 meters, WLAN (Wireless Local Area Network) has a range of 100 to 1000 meters, WNAN (Wireless Neighborhood Area Network) has a range of 5 to 10 kilometers and WWAN (Wireless Wide Area Network) a range of more than 100 kilometers.

Among the benefits generated by the Internet of Things (IOT) in the transport sector are:

1. Data Collection

It allows collecting vehicle data through installed sensors, thus providing detailed information on vehicle performance and driver behavior. When this data is analyzed, it can translate into significant gains and efficiency for the entire fleet.

2. Automatic recognition

The connection between devices, cloud and platform makes it possible to know almost automatically the status of the routes and possible improvements.

3. New tracking methods.

Before, scanning barcodes was more efficient; however, with the Internet of Things (IoT), it is cheaper to use sensors to track packets. Detailed updates let customers know exactly when their delivery arrives.

4. **Real-time data**.

Having vehicles connected by IoT allows real-time access to data that helps optimize logistics and times between loading point and destination. Knowing exactly the weight, dimensions and units of the product helps to select the best routes and the choice of the right vehicles to transport them.

5. **Fault detection.**

The Internet of Things (IoT) applied to logistics also makes it possible to detect failures or even accidents in the maintenance of goods. This helps prevent occupational hazards and product loss.

For the third research question, different projects that include vehicle tracking systems were examined. Table 2 shows the characteristics of these studies and some of them are explained.

Table 2: IoT projects applied in different technologies

Study	Description
Information systems in public transport	Electronic anti-evasion passenger counting system. Work with RF, GPS, GPRS technologies and operating software (LUIS, 2013).
Design and implementation of tracking device smart satellite gps	Using a programmable controller adds voice, data and location communication capabilities with GSM / GPRS / GPS module can connect to virtually any GSM network in the world, compatibility with all 4 frequency bands used by the GSM standard (Gandara, 2020).
WLAN networks geolocation with mobile application	Development of a mobile application that allows the detection and monitoring of wireless networks, in addition to being able to share these networks with other users so that they can connect with their mobile devices (CUSME, 2019).
IoT platform for REMOTE tracking and monitoring of vehicle parameters	Installation of data reading and transmission modules in vehicles. Data retrieval and processing in XML/JSON format using a Web server (VILLAVICENCIO, 2020).
Development of Vehicle Tracking System using GPS and GSM Modem	The main function of a GPS receiver module is to obtain the coordinates of the vehicle. These coordinates are periodically sent to the Arduino Uno microcontroller. The Arduino Uno processes this information and then sends the location information via GSM to be transmitted over the mobile network to the user when requested or periodically. The modules and the microcontroller communicate through the Universal Asynchronous Receiver/Transmitter (UART) interface (Pham et al., 2013).
Establishing a lifelong learning Environment using Iot and learning Analytics	Learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which occurs. Some researches including Academic Analytics, Action Analytics, Educational Data Mining, Networked Learning, etc. trying to achieve the same purpose with that of learning analytics through different directions (Cheng & Liao, 2014).

Source: Authors

Several studies propose the integration of cloud technologies and IoT devices. They propose a case study on the integration of sensors with services deployed on cloud platforms. However, although they implement a case study, they do not provide details of said implementation, they do not propose mechanisms that facilitate the integration between application services and IoT devices. On the other hand, (Martínez Clares et al., 2017) propose an application architecture that facilitates the interaction between IoT devices and information processing and presentation services deployed in cloud environments. Despite using protocols and standards for communication between services, they do not provide mechanisms to guide the integration and interaction activities between GIS application services and IoT devices. The author (VILLAVICENCIO, 2020)developed a prototype of a remote vehicle tracking system, their used the Global System for Mobile Communications (GSM) and the Google Maps API. This solution consists of sending the location of the vehicle through the SMS service of a mobile phone, the GSM modem installed in the control center receives this message and updates the location information in a database. Location information is displayed using the Google Maps API built into the Web application. Provides three functions; the most recent location of the tracked vehicle, route history and route planner. The fact that this solution is based on a mobile phone allows it to be adapted to any object that requires tracking without the need for costlyinvestment.

For the fourth research question, different development projects were analyzed that include methodologies, of which table 3 shows the results obtained:

Table 3: Methodologies in development projects

Reference	Methodology
(Rodríguez lópez et al., 2017),(McGrath & Whitty, 2020)	PMI,
(Robles-sandoval et al., 2019),(Velasquez et al., 2017)	Design Science
(CUSME, 2019),(Solórzano Ávila, 2018),(Modelado et al., 2018)(Velásquez Cardenas, Bryan Enrique; Solier Collazos, 2022)	Xtreme Programming (XP), Mobile-D and SCRUM
(Cárdenas, 2014),(Lauridsen et al., 2016),(LUIS, 2013)(Gomez, 2019),(Trab et al., 2018)	Own authors
(Mishra et al., 2018)	Knowledge based on data cycle time
(VILLAVICENCIO, 2020), (Sturmey et al., 2020)	AUP

Source: Authors.

These methodologies in the development of different projects have been coupled based on the needs of authors and the scope they wanted to achieve, there are methodologies such as the PMI which is a process, with specific duration and a specific purpose, made up of activities and tasks different, which can be developed gradually through the execution of processes, using knowledge, skills, tools and management techniques.

AUP or agile unified process can be the set of agile methodologies that allow an adequate optimization of a software project that can be appreciated in mathematical concepts. Represents a reasonable alternative to conventional software engineering for certain classes of software and in some types of projects. It has also been shown to rapidly terminate successful systems.

Scrum is especially suitable for projects in complex environments and where results need to be obtained quickly, where requirements are changing or poorly defined, where innovation, competitiveness, flexibility, and productivity are essential.

The own author's methodologies are methodologies that have been used based on existing methodologies but modified by each author, changing or combining methodologies for their own development based on the needs of each author's project.

For the fifth research question, a search was made for simulators that are used for vehicular traffic. Table 4 shows the most representative:

Table 4: Vehicle traffic simulators

References	Simulator
(ptv group, 2021) (Gazder et al., 2020)(Blomgren & Jungbjer, 2019)(Botan & Weichbrodt, 2020)(Delgado,2020)(Con& Vulnerables,2019)(Sadat & Celikoglu,2017) (La et al., 2017)(Chen et al., 2019)	PTV VISSIM
(Barbecho Bautista et al., 2021)(Kusari et al., 2021)(Validi et al., 2021)(Lopez et al., 2018) (Koch et al., 2021)(Mahmud et al., 2019)	SUMO
(David & Ciurana, 2021)(Moll et al., 2021) (Project et al., 2022) (Hasibur Rahman & Abdel-Aty, 2020) (Othman et al., 2023) (Tumminello & Gran, 2022) (Elmorshedy et al., 2022) (Nahmias-Biran et al., 2022) (Gasparinatou et al., 2021)(José & Valenzuela, 2020)	AIMSUM NEXT

Source: Authors

In figure 2 it can be seen that SUMO has the highest search result in google scholar with more than 9240 searches, followed with Aimsum Next with 3310 results and VT Vissim with 1470 results. Sumo is positioned in the first place because it is open source, and does not use a license as the other two mentioned.

PTV Vissim is a global standard for traffic and transportation planning that offers a realistic and detailed view of road flow status and its impacts, with the ability to define multiple what-if scenarios. You can map networks in detail and model different polygons.

SUMO is an open source and traffic simulator. It allows you to model intermodal traffic systems, including road vehicles, public transport, and pedestrians. It includes supporting tools that automate the main tasks for creating, running, and evaluating traffic simulations, such as network import, route calculations, visualization, and emission calculations.

AIMSUM can create scenarios with different options for network topology, transport demand, traffic light control, and public transport schedules, providing an efficient method of generating multiple variants of a traffic model. Geometry Settings allow projects to be coded as a set of network changes that can be triggered, individually or together.

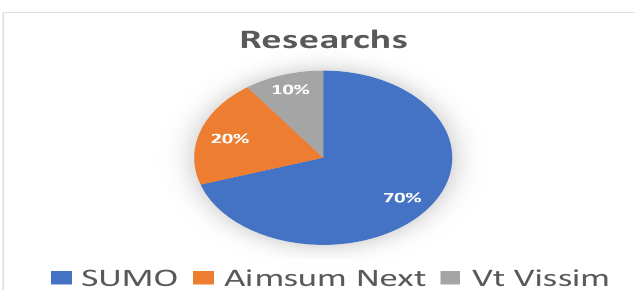

Figure 2: Percentage of search results of traffic simulations

Table 5: Simulator features

Simulator	Feauture				
	Hybrid simulator	Open source	Traffic and risk analysis	Traffic management improvements	Transit simulation
SUMO	✓	✓	✓	✓	✓
Aimsum Next	✓	X	X	✓	✓
VT Vissim	X	X	✓	✓	✓

Source: Authors

CONCLUSIONS

For the development of this study, a centralized search of everything that IoT entails as technology was carried out, applying an information filter, the search could be reduced to the most important and relevant for the research development, which could conclude important aspects of this technology.

In the communication process, IoT is evolving with the interaction of devices with each other currently, there are devices and sensors whose communication through the internet is carried out easily and directly, in the same way, there are older devices whose communications by their standard are more complex. Each manufacturer of these technologies has its own communication protocol which means that not all devices are compatible, which is why the research was important to know the different technologies and protocols to buy them, pay for them, differentiate them for optimal development and that they are within reach. necessary. Sigfox and LoRa have coverage in large countries such as the United States or the Netherlands, where the highest peaks in the use of this technology.

A search and study of different IoT projects were carried out, covering different methods, architectures and hardware and software components, which had a better understanding for the technological development of these components for research. Different simulations about vehicular traffic were analyzed knowing the scope of each one of them as their advantages and disadvantages, this information was important since this type of technology is relatively new which contributes a lot in the fundamentals of development and behavior at the time of simulating vehicular traffic.

With the results obtained, it is expected to continue expanding information and knowledge of future research, since the field of IoT advances and grows exponentially in developed countries, it is a new technology in continuous growth on its adaptability in the dissemination of information. At the moment it is expected that the information contained in this article may be useful for research that requires information relevant to IoT technologies. The advantages and disadvantages of these technologies, their scope and improvements for decision making were analyzed. This partially new technology has an important boom in technological progress and automation, which opens its doors to future and better projects, and generates new forms of work and studies.

Conflict of interests

The authors authorize the distribution and use of their article.

Contribution of the authors

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3. Formal analysis: Wilmer Moreira Sánchez and Leonardo Chancay-García
4. Research: Wilmer Moreira Sánchez and Dannyll Michellec Zambrano
5. Methodology Wilmer Moreira Sánchez
6. Supervision: Dannyll Michellec Zambrano and Leonardo Chancay-García
7. Validation: Dannyll Michellec Zambrano and Leonardo Chancay-García
8. Drafting: Wilmer Moreira Sánchez and Leonardo Chancay-García

BIBLIOGRAPHY

Abawajy, J., Darem, A., & Alhashmi, A. A. (2021). Feature subset selection for malware detection in smart iot platforms. *Sensors (Switzerland)*, *21*(4), 1–19. https://doi.org/10.3390/s21041374

Barbecho Bautista, P., Urquiza-Aguiar, L. F., & Aguilar Igartua, M. (2021). STGT: SUMO-Based Traffic Mobility Generation Tool for Evaluation of Vehicular Networks. *PE-WASUN 2021 - Proceedings of the 18th ACM Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks*, 17–24. https://doi.org/10.1145/3479240.3488523

Blomgren, M., & Jungbjer, P. (2019). *Emissions Modeling of Electric Urban Transit - Analysis of Environmental Effects of Electric Public Transit in Johanneberg by using the Software PTV Vissim and EnViVer*. 74.

Botan, F., & Weichbrodt, J. (2020). *Congestion in public transport system A micro-simulation analysis of congestion in public transport in Brunnsparken and Centralstationen by using software PTV Vissim*.

Cárdenas, N. C. (2014). *Computacion En La Nube Cloud Computing*. 46–51.

Chen, C., Zhao, X., Liu, H., Ren, G., Zhang, Y., & Liu, X. (2019). Assessing the influence of adverse weather on traffic flow characteristics using a driving simulator and VISSIM. *Sustainability (Switzerland)*, *11*(3). https://doi.org/10.3390/su11030830

Cheng, H. C., & Liao, W. W. (2014). Establishing an lifelong learning environment using IOT and learning analytics. *International Conference on Advanced Communication Technology, ICACT*, 1178–1183.

Con, T., & Vulnerables, U. (2019). *Fabio Gutiérrez Álvarez*.

CUSME, M. K. P. (2019). Aplicación Móvil De Geolocalización De Redes Wlan. *Escuela Superior Politécnica Agropecuaria De Manabí Manuel Félix López Dirección*, 1–74. http://repositorio.espam.edu.ec/bitstream/42000/1055/1/TTMAI5.pdf

David, A., & Ciurana, M. A. S. (2021). *Predicción de tráfico interurbano con datos de vehículo conectado*.

Delgado, A. (2020). Design of a 3D control system using PTV-VISSIM to manage Vehicle traffic. *International Journal of Emerging Trends in Engineering Research*, *8*(5), 1819–1823. https://doi.org/10.30534/ijeter/2020/55852020

Elmorshedy, L., Abdulhai, B., & Kamel, I. (2022). Quantitative Evaluation of the Impacts of the Time Headway of Adaptive Cruise Control Systems on Congested Urban Freeways Using Different Car Following Models and Early Control Results. *IEEE Open Journal of Intelligent Transportation Systems*, *3*(April), 288–301. https://doi.org/10.1109/ojits.2022.3166394

Endesa, F. (2021). *Smart Cities*. Smart Cities.

Gandara. (2020). *"DISEÑO Y IMPLEMENTACIÓN DE DISPOSITIVO DE RASTREO SATELITAL INTELIGENTE GPS MEDIANTE MICROCONTROLADOR PROGRAMABLE CON ACTIVACIÓN DE APAGADO AUTOMÁTICO MEDIANTE ZONAS POLIGONALES EN GOOGLE MAP*.

Gándara, M. L. (2020). *DISEÑO E IMPLEMENTACIÓN DE UN SISTEMA DE SEGUIMIENTO GPS PARA LA LOCALIZACIÓN Y RASTREO DE ELEMENTOS MÓVILES*. http://castor.det.uvigo.es:8080/xmlui/bitstream/handle/123456789/441/LorenzoGándaraManuel.pdf?sequence=1&isAllowed=y

Gasparinatou, C., Oikonomou, M. G., Casas, J., Slu, A., Djukic, T., Vlahogianni, E. I., Yannis, G., & Gasparinatou, Y. (2021). *Passenger Car Unit Values of Connected Autonomous Vehicles in Urban Road Networks 2 3 Department of Transportation Planning and Engineering Athina Tympakanaki*.

Gazder, U., Alhalabi, K., & AlAzzawi, O. (2020). Calibration of autonomous vehicles in PTV VISSIM. *IET Conference Publications*, *2020*(CP777), 39–42. https://doi.org/10.1049/icp.2021.0752

Gomez, D. (2019). *Arquitectura Iot Para La Prestación Del Servicio De Semaforización Inteligente En Bogotá*. 97.

González, R., & Gutiérrez, A. (2017). Competencias mediática y digital del profesorado e integración curricular de las tecnologías digitales. *Revista Fuentes*, *19*(2), 57–67. https://bit.ly/3kCxZgC%0Ahttps://revistascientificas.us.es/index.php/fuentes/article/view/4028

Hasibur Rahman, M., & Abdel-Aty, M. (2020). Application of Connected and Automated Vehicles in a Large-Scale Network by Considering Vehicle-to-Vehicle and Vehicle-to-Infrastructure Technology. *Transportation Research Record*, *2675*(1), 93–113. https://doi.org/10.1177/0361198120963105

JACOBSON, R. M. (2017). Comparativa y estudio de plataformas IoT. *Universidad de Catalunya*, *8.5.2017*.

José, A., & Valenzuela, C. (2020). *Implementación de mejoras heurísticas para la búsqueda de caminos en Aimsun Next*.

Koch, L., Buse, D. S., Wegener, M., Schoenberg, S., Badalian, K., Dressler-, F., & Andert, J. (2021). Accurate physics-based modeling of electric vehicle energy consumption in the SUMO traffic microsimulator. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC*, *2021-Septe*, 1650–1657. https://doi.org/10.1109/ITSC48978.2021.9564463

Kusari, A., Li, P., Yang, H., Punshi, N., Rasulis, M., Bogard, S., & LeBlanc, D. J. (2021). *Enhancing SUMO simulator for simulation based testing and validation of autonomous vehicles*. http://arxiv.org/abs/2109.11620

La, A. D. E., Matemática, S., El, E., Solano, B. R., Anthony, E., Terrones, B. R., & Danitza, N. (2017). *AUTORES : ASESOR :*

Lauridsen, M., Kovács, I. Z., Mogensen, P., Sørensen, M., & Holst, S. (2016). Coverage and capacity analysis of LTE-M and NB-IoT in a rural area. *IEEE Vehicular Technology Conference*, *0*. https://doi.org/10.1109/VTCFall.2016.7880946

Lopez, P. A., Behrisch, M., Bieker-Walz, L., Erdmann, J., Flotterod, Y. P., Hilbrich, R., Lucken, L., Rummel, J., Wagner, P., & Wiebner, E. (2018). Microscopic Traffic Simulation using SUMO. *IEEE Conference on Intelligent Transportation Systems, Proceedings, ITSC, 2018-Novem*, 2575–2582. https://doi.org/10.1109/ITSC.2018.8569938

LUIS, A. (2013). *SISTEMA DE INFORMACION DE GESTION PUBLICA*.

Mahmud, S. M. S., Ferreira, L., Hoque, M. S., & Tavassoli, A. (2019). Micro-simulation modelling for traffic safety: A review and potential application to heterogeneous traffic environment. *IATSS Research*, *43*(1), 27–36. https://doi.org/10.1016/j.iatssr.2018.07.002

Martínez Clares, P., Pérez Cusó, F. J., & Martínez Juárez, M. (2017). Aplicación de los modelos de gestión de calidad a la tutoría universitaria. *Revista Complutense de Educación*, *29*(3), 633–649. https://doi.org/10.5209/rced.53541

McGrath, S., & Whitty, S. J. (2020). Practitioner views on project management methodology (PMM) effectiveness. *Journal of Modern Project Management*, *8*(1), 188–215. https://doi.org/10.19255/JMPM02310

Mishra, S., Bhattacharya, D., & Gupta, A. (2018). Congestion adaptive traffic light control and notification architecture using google maps APIs. *Data*, *3*(4). https://doi.org/10.3390/data3040067

Modelado, A. L., La, Y. A. D. E., Bohorquez, C., Yulexi, V., Jiménez, A., & Luis, J. (2018). *UNIVERSIDAD DE GUAYAQUIL FACULTAD DE CIENCIAS MATEMÁTICAS Y FÍSICAS PLANEACIÓN URBANA EN LA CIUDAD DE GUAYAQUIL DIRIGIDO A LA TRANSPORTACIÓN , ENFOCADO*.

Moll, S., López, G., & García, A. (2021). Analysis of the influence of sport cyclists on narrow two-lane rural roads using instrumented bicycles and microsimulation. *Sustainability (Switzerland)*, *13*(3), 1–17. https://doi.org/10.3390/su13031235

Nahmias-Biran, B.-H., Dadashev, G., & Levi, Y. (2022). Demand Exploration of Automated Mobility On-Demand Services Using an Innovative Simulation Tool. *IEEE Open Journal of Intelligent Transportation Systems*, *3*(December 2021), 580–591. https://doi.org/10.1109/ojits.2022.3197709

Othman, K., Shalaby, A., & Abdulhai, B. (2023). Dynamic Bus Lanes Versus Exclusive Bus Lanes: Comprehensive Comparative Analysis of Urban Corridor Performance. *Transportation Research Record*, *2677*(1), 341–355. https://doi.org/10.1177/03611981221099517

Peña Queralta, J., Gia, T. N., Zou, Z., Tenhunen, H., & Westerlund, T. (2019). Comparative study of LPWAN technologies on unlicensed bands for M2M communication in the IoT: Beyond Lora and Lorawan. *Procedia Computer Science*, *155*(2018), 343–350. https://doi.org/10.1016/j.procs.2019.08.049

Pham, H. D., Drieberg, M., & Nguyen, C. C. (2013). Development of vehicle tracking system using GPS and GSM modem. *2013 IEEE Conference on Open Systems, ICOS 2013*, 89–94. https://doi.org/10.1109/ICOS.2013.6735054

Pradyumna Gokhale1, Omkar Bhat2, S. B. (2019). Introduction to IOT. *System Engineering For IMS Networks*, 1–24. https://doi.org/10.1016/b978-0-7506-8388-3.00001-0

Project, F. D., Vicente, A. L., Benet, E. B., & Sole, D. B. (2022). *Bachelor ' s degree in Industrial Technology Engineering Traffic microsimulation of Autonomous Vehicles Flow in Ronda de Dalt of Barcelona Escola Tècnica Superior d ' Enginyeria Industrial de Barcelona*. *July*.

ptv group. (2021). *PTV Vissim*. https://www.ptvgroup.com/es/soluciones/productos/ptv-vissim-nuevo/

Robles-sandoval, S., Tecnológico, I., Rica, D. C., Vásquez-carvajal, H., Tecnológico, I., Rica, D. C., Naranjozeledón, L., Tecnológico, I., & Rica, D. C. (2019). *Adaptación de la metodología de ciencia de diseño en el desarrollo de luminarias Adapting Design Science Methodology in luminaires development*. 74–79.

Rodríguez lópez, D., Rodríguez lópez, J., Zúñiga prieto, M., & Solano, L. (2017). *Un enfoque para la integración de dispositivos IoT en el desarrollo de SIG en la nube*. 57–65.

S.A., P. del S. (2016). *Los países que llevan la delantera en la Internet de las Cosas*.

Sadat, M., & Celikoglu, H. B. (2017). Simulation-based Variable Speed Limit Systems Modelling: An Overview and A Case Study on Istanbul Freeways. *Transportation Research Procedia*, *22*(2016), 607–614. https://doi.org/10.1016/j.trpro.2017.03.051

Solórzano Ávila, J. A. (2018). *Desarrollo de una aplicación web multiplataforma usando el framework django, para publicitar eventos sociales, aplicado en el municipio del Cantón Morona*. http://dspace.espoch.edu.ec/handle/123456789/9103

Sturmey, P., Taylor, J. L., & Lindsay, W. R. (2020). Information system for the management of intelligent traffic lights. *Offenders with Developmental Disabilities*, 327–350. https://doi.org/10.1002/9780470713440.ch17

Trab, S., Bajic, E., Zouinkhi, A., Naceur Abdelkrim, M., & Chekir, H. (2018). RFID IoT-enabled warehouse for safety management using product class-based storage and potential fields methods. *International Journal of Embedded Systems*, *10*(1), 71–88. https://doi.org/10.1504/IJES.2018.089436

Tumminello, M. L., & Gran, A. (2022). *Connected and Automated Vehicles Navigating Roundabouts*.

Validi, A., Morales-Alvarez, W., & Olaverri-Monreal, C. (2021). Analysis of the Battery Energy Estimation Model in SUMO Compared with Actual Analysis of Battery Energy Consumption. *Iberian Conference on Information Systems and Technologies, CISTI*. https://doi.org/10.23919/CISTI52073.2021.9476579

Vejlgaard, B., Lauridsen, M., Nguyen, H., Kovacs, I. Z., Mogensen, P., & Sorensen, M. (2017). Coverage and Capacity Analysis of Sigfox, LoRa, GPRS, and NB-IoT. *IEEE Vehicular Technology Conference*, *2017-June*. https://doi.org/10.1109/VTCSpring.2017.8108666

Velásquez Cardenas, Bryan Enrique; Solier Collazos, J. (2022). *Sistema inteligente de gestión de tráfico*.

Velasquez, N., Medina, C., Castro, D., Acosta, J. C., & Mendez, D. (2017). Design and development of an iot system prototype for outdoor tracking. *ACM International Conference Proceeding Series*, *Part F1305*, 15–20. https://doi.org/10.1145/3102304.3105575

VILLAVICENCIO, I. jacobo. (2020). *PLATAFORMA IOT PARA EL RASTREO PARÁMETROS DE VEHÍCULOS Y MONITOREO REMOTO DE*. 2004–2005.

Zemrane, H., Baddi, Y., & Hasbi, A. (2019). Ehealth smart application of WSN on WWAN. *ACM International Conference Proceeding Series*, *Part F1481*. https://doi.org/10.1145/3320326.3320358

Zorbas, D., & O'Flynn, B. (2019). Autonomous collision-free scheduling for lora-based industrial internet of things. *20th IEEE International Symposium on A World of Wireless, Mobile and Multimedia Networks, WoWMoM 2019*. https://doi.org/10.1109/WoWMoM.2019.8792975