Prototype for monitoring noise pollution as a tool for the empowerment of society

Prototipo para el monitoreo de la contaminación acústica, como herramienta para el empoderamiento de la sociedad

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Abstract

Objective— Acceptable levels are between 45 and 65 dB according to the OMS, exceeding these values can affect mental and physiological health, deteriorating the quality of life of the inhabitants. The purpose of this research is to identify the levels of noise pollution in the historic center of the city of Popayán, Cauca, Colombia, during peak hours of midday.

Methodology— Applying the Design Thinking methodology, a prototype based on the Internet of Things (IoT) and a mobile application were designed to monitor the acoustic level in real time, and thus offer a technological tool that contributes to the empowerment of society in relation to its environmental conditions.

Results— The software solution was developed for Android mobile devices, in operating system versions higher than 6.0 (Marshmallow), using tools such as Android Studio and Firebase. As a perspective of this work, it is suggested to make measurements for longer periods of time, and in several places in the city.

Conclusions— Real-time measurements of the level of noise pollution, for example, through the application and measurements made during 9:11 a.m. and 6:31 p.m., on February 11, 2022, it was possible to deduce that the average level of noise pollution was 61.48 dB and that, in the measurements made in the morning, they were the ones with the highest levels of pollution. , being the data of 11:01 a.m.

Keywords— Noise pollution; IoT Prototype; application; monitoring; empowerment

Resumen

Objetivo— Los niveles aceptables están entre 45 y 65 dB según la OMS, al superar estos valores se puede afectar la salud mental y fisiológica, deteriorando la calidad de vida de los habitantes. El objeto de esta investigación es identificar los niveles de contaminación acústica en el centro histórico de la ciudad de Popayán, Cauca, Colombia, en horas pico del mediodía.

Metodología— Aplicando la metodología Design Thinking se diseñó un prototipo basado en Internet de las Cosas (IoT) y una aplicación móvil que permite monitorear el nivel acústico en tiempo real, y así, ofrecer una herramienta tecnológica que contribuya al empoderamiento de la sociedad en relación a sus condiciones ambientales

Resultados— La solución software fue desarrollada para dispositivos móviles Android, en versiones de sistema operativo superiores a la 6.0 (Marshmallow), utilizando herramientas como Android Studio y Firebase. Como perspectiva de este trabajo, se sugiere hacer mediciones por periodos de tiempo más prolongados, y en varios sitios de la ciudad.

Conclusiones— las mediciones en tiempo real del nivel de contaminación acústica, por ejemplo, por medio de la aplicación y las mediciones realizadas durante las 9:11 a.m. y las 6.31 p.m., del día 11 de febrero de 2022, se pudo deducir que el promedio del nivel de contaminación acústica fue de 61.48 dB y que, en las mediciones realizadas en horas de la mañana, fueron las que tuvieron niveles más altos de contaminación, siendo el dato de las 11:01 a.m.

Palabras clave— Contaminación acústica; prototipo IoT; aplicación; monitoreo; empoderamiento

I. Introductionn

According to the WHO, noise pollution is one of the most important environmental problems in the world, along with air pollution [1]. Excessive noise brings negative health effects such as deafness, psychopathological problems (increased blood pressure, headache, respiratory deficiencies, gastritis), psychological problems (anxiety, stress, depression), lack of concentration and memory loss [2]-[4]. Today's society must support this emergency, but it is also the main source of generation.

During the last decade, noise pollution has increased significantly, and currently most urban environments exceed of 50 decibels (dB) the limit supported by the human ear. Crowded environments such as shopping malls, recreation areas, university environments, considerably exceed these levels [5], [6].

Although vehicular noise is established in the low frequency category, in cities due to the heavy traffic that occurs, it also becomes an environmental problem to consider. For example, noise from vehicular traffic in the city of Popayán, Cauca, Colombia, is a problem that is evident mainly during peak hours and in very busy areas such as the historic center.

There are several options to measure noise using sensors, dosimeters, sound level meters, digital meters, etc. [7], [8]. However, most of these solutions are expensive and technical skills are required for their installation, maintenance and constant monitoring. With the emergence of new technologies such as the Internet of Things (IoT), faster and more stable internet connections, greater coverage, it is possible to propose solutions for real-time monitoring of noise levels.

The objective of this research is to propose a technological solution based on IoT that allows identifying the levels of noise pollution in the center of the city of Popayán, using a mobile application (for Android devices). This type of solution provides information in real time, which can be very useful for decision makers related to environmental, health, and environmental management of the city. In addition, as it is a tool that is available to society in general, it becomes an instrument for empowering communities, who will be able to learn about and act on the situation of noise pollution in their environment.

The rest of the document is structured as follows: Section 2 presents the works related to the research, highlighting the main advances and contributions in various contexts. Section 3 shows the methodology used for the development of the research. The main results are shown in section 4. And finally the conclusions and perspectives are presented.

II. Background

Noise is measured on the decibel (dB) scale, and according to the WHO, the noise limit should not exceed 65 dB during the day and 55 dB at night, if these levels are exceeded , it becomes a condition detrimental to health. This is more critical if the exposure is continuous and prolonged, affecting the physical and mental health of people [9].

In 2013, a study presented noise modeling in the city of Bogotá, Colombia. This proposal was based on the evaluation of a model for the prediction of dynamic traffic based on noise curves for vehicle classes and their speed, in order to simulate specific conditions and compare them with European models [10].

At the Latin American level, the Historic Center of Mexico City, in 2015, was the scene of an investigation that developed a distributed wireless monitoring system, where each node uses a pre-polarized IEC 61672 Class 1 microphone and a wireless connection. to the internet via 3G networks. The measurements were carried out for 3 years and finally served to take corrective actions, such as the pedestrianization of some streets of the Historic Center, the direction of circulation of others was changed, heavy traffic and the moderate use of whistles by residents were prohibited. traffic control officers [11].

Noise pollution occurs in many spaces, hospitals are no exception. In Cartagena, Colombia [12], the continuous level of noise in a neonatal intensive care unit is studied, and noise levels are correlated with burnout syndrome (type of work stress), which is characterized by physical and mental exhaustion, impacting the self-esteem of those who suffer from it. In another investigation, the noise in the intensive care units of a public university hospital in Santa Marta

(Colombia) is monitored, identifying the main sources of contamination and the hours in which there is more affectation [13].

In 2017, in Chile, a low-cost IoT-based environmental monitoring system was applied (approximately US $150), in order to raise awareness about pollution, the variables measured were: Carbon Monoxide (CO), temperature, relative humidity, particulate matter 2.5, noise and UV radiation, measurements made through sensors and data stored in a MySQL database and then in a local Apache web server [14].

Environmental culture is a determining point for the reduction of any type of contamination, he UPN (Colombia) proposes the reduction of the gap from behaviors focused on attitudes, norms and the teaching of rules in favor of the protection of the planet [15]. In this process of creating awareness, more countries worldwide are beginning to delve into this issue, in Ecuador a study was carried out on noise in the city of Quito, with the aim of developing the first noise map of the city and estimating the population exposed [16].

In India, one of the most populous countries in the world, in 2018, a vehicle pollution control system was proposed using IoT, real-time measurement, using sensors, arduino, smartphones and mobile apps to show the data [17].

Regarding noise pollution and health effects, there are several works, including a study on the effects of noise on heart rate and mood, showing that exposure to noise increases heart rate by a 4% and there is a correlation between this and mood and cognition [18], [19].

In Colombia, studies on this subject are limited, and in the context of the city of Popayán, only the environmental noise map was carried out by the Cauca Regional Autonomous Corporation (C.R.C.), identifying the most critical points of the city. Despite this initiative, no concrete tool is provided that allows the empowerment of the community in these environmental issues, and constant monitoring is not carried out to help decision makers to efficiently manage mobility and the environmental conditions of the city.

For the design of this prototype for measuring noise pollution levels, the final degree project carried out by Carlos Rojo Horno was used as a reference, of the Rovira I Virgili University in Tarragona (Spain), in 2017, which consisted of the design of a sound level meter, based on IoT, using an Arduino Uno R3 card as a development board, a Wi-Fi module and a MAX9814 sensor, which It was connected via Wi-Fi networks to ThingSpeak, this being the web platform used to view the measurements [20].

III. Methodology

For the development of the project, the Design Thinking (D.T.) methodology [21] was considered. The exploration phase initially presented in this article is equivalent to the phases of empathizing, defining and ideating (D.T.), while the development phase corresponds to prototyping (D.T.), and the evaluation phase is similar to evaluating (D.T.).

A. *Exploration Phase*

A literature review was carried out on the problem raised, investigating and consulting the various technologies based on IoT, and studies related to the project. Similarly, the focus group technique was used [22], with 10 participants, including students, university workers, museum workers, to empathize with people who remain continuously in the sector where the study was carried out. (historical Center). Subsequently, with the information collected, the requirements that the proposed solution must have are defined, mainly including the implementation of a mobile application that is easy to use for anyone, and that provides information that efficiently helps to empower the affected communities. due to noise pollution problems.

B. *Development Phase*

A low-cost IoT-based prototype was developed to identify noise pollution levels, using a MAX9814 sensor on an Arduino ESP-WROOM32 card, using the Arduino IDE as a development environment to capture sensor data and convert it. to dB and then send them to the Firebase Realtime Database, using the FirebaseESP32.h and ArduinoJson.h libraries, among others, for storage, being necessary to have a Google email account, in this way the sensor captures the data every minute and the sent via Wi-Fi to the database for storage (Fig. 1).

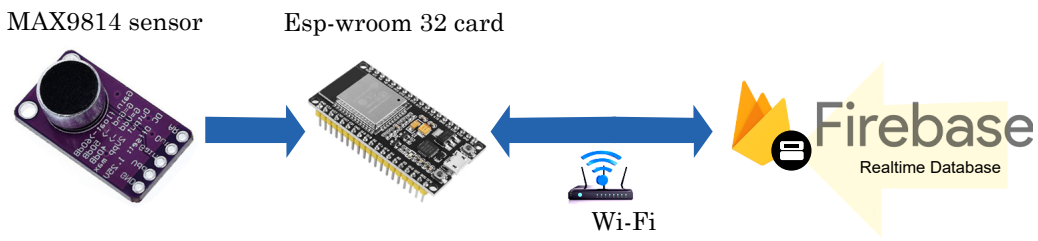

Fig. 1. Architecture of the prototype.
Source: Authors.

A mobile application Acoustic level was developed, designed for Android devices, in its versions equal to or greater than 6.0 or Marshmallow and a memory space of 31.83 Mb, in order to be able to visualize the data captured by the sensor in real time. From the stimulus generated by the agent, Android Studio was used as the development environment and Kotlin as the language, making it necessary to first create a project in Firebase and then connect it to the Android project using the applicationId and the google-service.json file and with Arduino IDE, through the project_id, which in this case was called sound level meter-88724, leaving Android Studio, Realtime Database and Arduino IDE connected.

The implementation of the IoT solution was done in the ninth race (9) between 4th and 5th streets, since it is one of the busiest streets in the center of the city of Popayán (Colombia), and thus to know the levels of noise and noise pollution that produce in this way. Seeking to raise awareness and increase the active participation of citizens on the environmental impacts that they are causing in their daily activities, and with the data obtained, contribute to decision-making aimed at promoting sustainable development in the region. In this place, a node was implanted where the Arduino board captured the data from the sensor and carried out the mathematical process established in the code, the result was sent to the coordinating node in which the data obtained is stored in a CSV file, then a statistic of the data is obtained and alarms are generated if the results exceed the levels allowed by the regulations. Fig. 2 shows the strategic points for noise measurement geographically in a satellite view.

Fig. 2. Strategic points for noise measurement.
Source: Authors.

C. *Evaluation phase*

In this phase of the research project, the functioning of the prototype and the application were evaluated through a survey, and because this project is part of the work carried out in the Guillermo León Valencia Museum House, in the city of Popayán (Colombia), they were the ones who evaluated from their different points of view the aspects of the project and its operation (Fig. 3).

Fig. 3. Staff of the House Museum with the application.
Source: Authors.

IV. Evaluation and Results

With the data capture, a relationship was made between the values obtained from the KY-038 sensor and the ambient sound values (in Decibels). For them, several measurements of sound pressure were taken at the two points (node A and Coordinator node), the Koolerton brand sound level meter was used, at different sound levels, and it was compared with the data delivered by the Arduino Uno board obtained from the sensor. KY-038, establishing a linear trend relationship between them. For this process, the mathematical tool of linear regression is used, this in order to define the reference value at each point and then Fig. 4 and Fig. 5 are shown with the measurements made by both the sound level meter and the sensor.

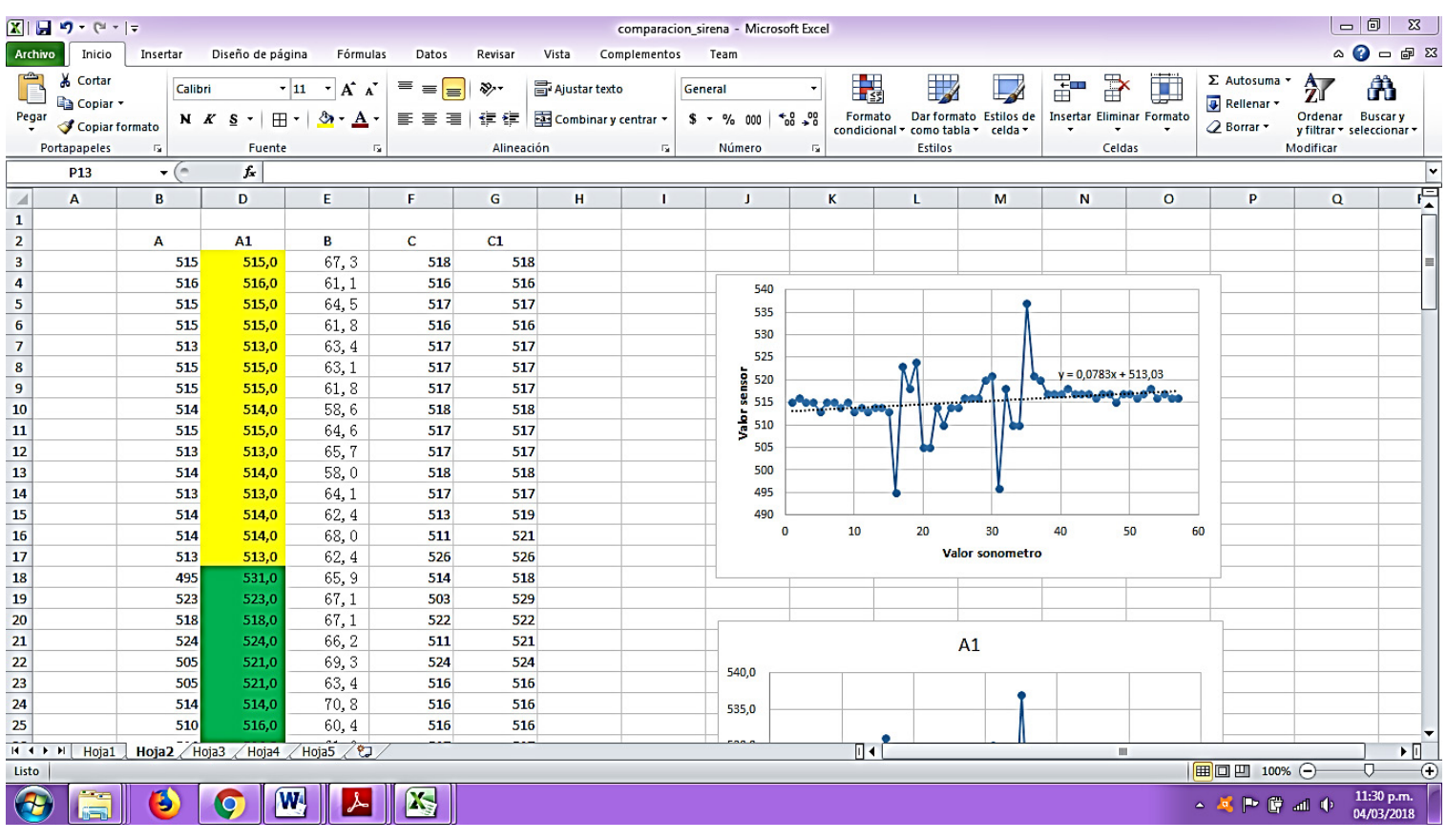

Fig. 4. Monitoring level of noise pollution with the sound level meter.
Source: Authors.

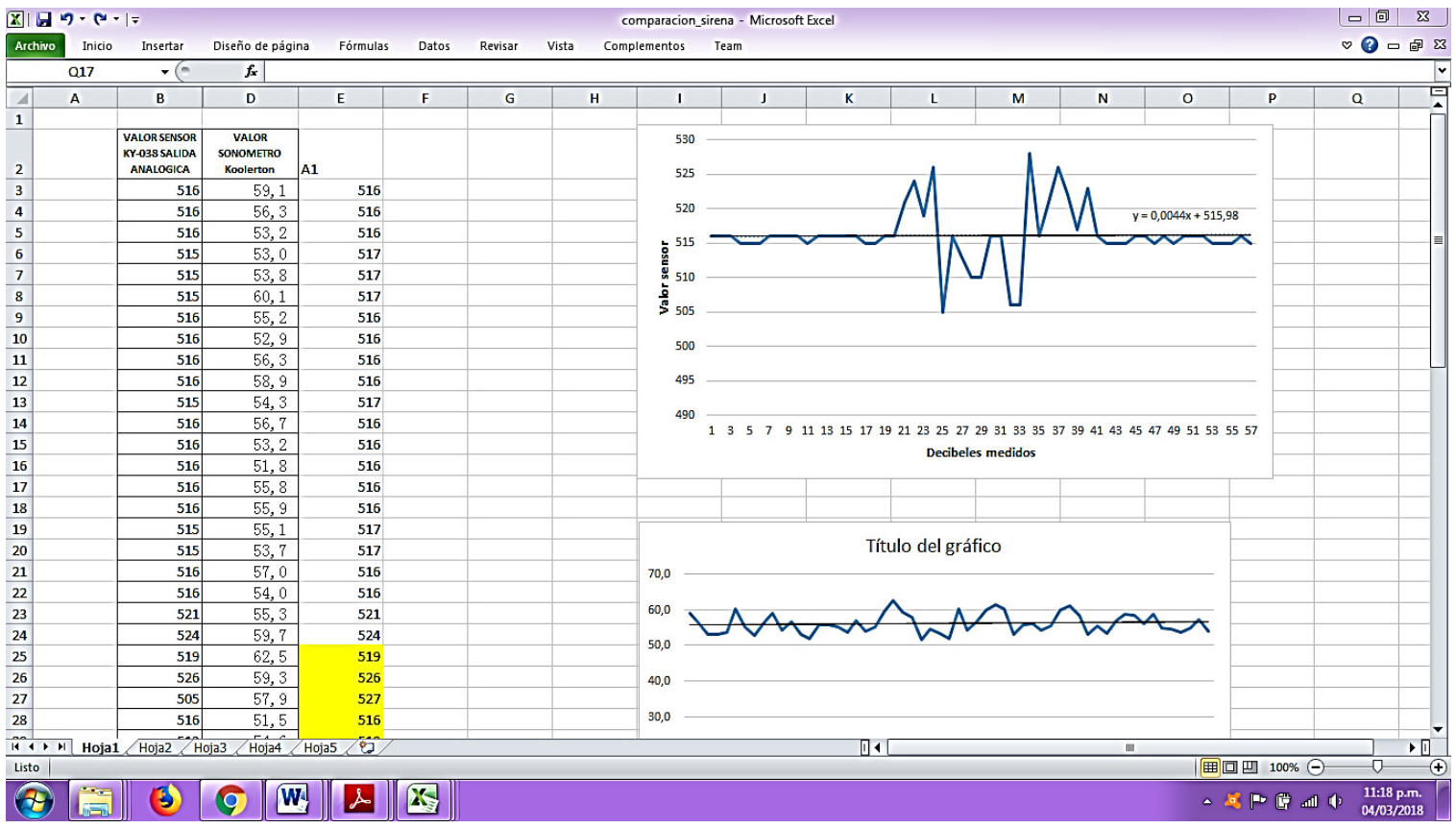

Fig. 5. Monitoring level of noise pollution with the sensor.
Source: Authors.

By making the linear relationship between the sensor and the Koolerton sound level meter, it can be established:

1) Noise levels are in ranges of 50 and 60 dB at their highest peaks. This figure is worrying since environmental and vehicular acoustic noise is generating a noise pollution problem in the measured area. This area is also frequented daily by a significant number of people since it is a main road in the historic center of the city and there are universities, notaries, churches, primary and secondary schools, among others.
2) Although the sensor turns out to be more sensitive than the sound level meter, both indicate noise levels outside the normal range, which is not only a tangible alert for the competent entities, but also for the people who contribute to the generation of this noise and whose stay is permanent or adjacent to this road.
3) The Koolerton sound level meter is not the most suitable for capturing information, since it is not efficient since its sensitivity is not adequate to capture sound waves in any environment.

A. *Prototype validation results*

For this process, the personnel who work in the facilities of the Casa Museo Guillermo León Valencia, Popayán (Colombia) were surveyed. A total of 10 people.

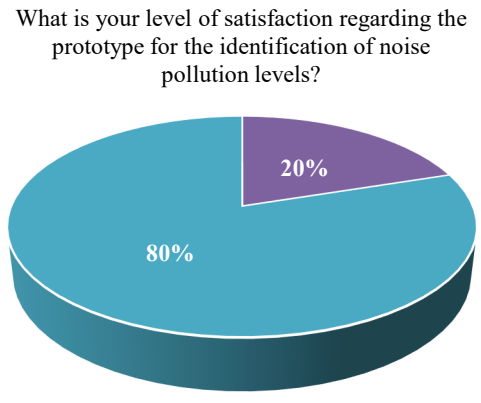

Fig. 6. Level of satisfaction in relation to the solution offered.
Source: Authors.

Next, the results obtained from the evaluation carried out by the end users of the offered technological solution are presented. Initially, the level of user satisfaction in relation to the tool was measured (Fig. 6).

According to those surveyed, 10% consider that the cost-benefit-quality ratio of the prototype is very good, while 90% rate it as excellent, thus determining that the cost-benefit-quality ratio is within the initially proposed by the client and/or user for the development of the project (Fig. 7).

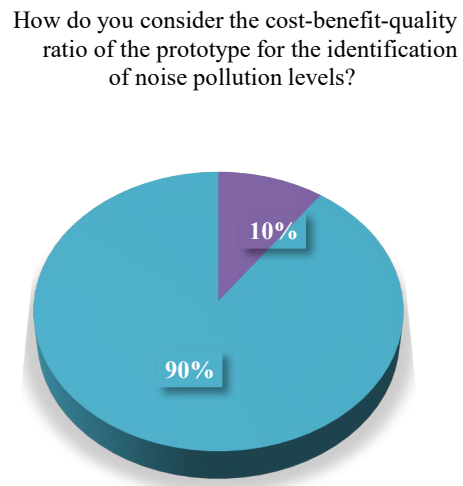

Fig. 7. Cost-benefit-quality ratio.
Source: Authors.

In relation to the functionality of the prototype (Fig. 8), 100% rate it as excellent, considering that it meets practicality and usefulness characteristics when performing its functions.

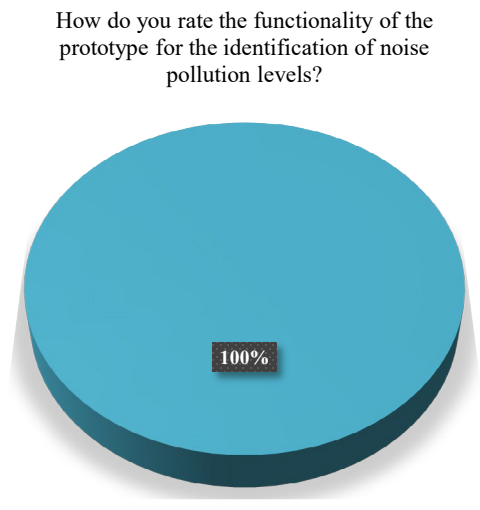

Fig. 8. Functionality of the prototype.
Source: Authors.

Regarding the appropriateness, comfort and practicality of the prototype design, 90% of people consider it excellent and only 10% very good (Fig. 9).

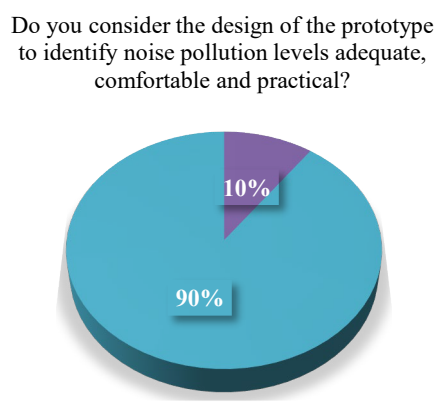

Fig. 9. Suitability, comfort and practicality in design.
Source: Authors.

In addition to the above criteria, the following were evaluated: i) the understanding and use of the application, 100% of users consider that it is very easy to use, mainly because of the speed, aesthetics, friendly and intuitive solution; ii) approval of the prototype, 100% of those surveyed would approve the use of these prototypes in order to monitor noise levels in the city, since people are becoming more aware of their hearing health and the consequences that noise can generate. high noise levels in the short, medium and long term; iii) application in other contexts, 100% of people consider that this type of prototype can help monitor and control problems associated with any type of pollution, given the importance, relevance and growth that the IoT has had and that it has driven the development of environmental monitoring and control applications.

Finally, several people surveyed suggested being able to integrate more sensors such as temperature, humidity and gases, because these are other factors that affect the city, as well as having the possibility of being able to turn on the prototype remotely.

V. Conclusions

Hearing health is becoming more relevant for society, although in some cities progress has been made on this issue, there is still a long way to go, with citizen behavior and road intelligence being important factors, essential to reduce these levels of noise pollution.

It was possible to clearly define the necessary requirements in order to design a prototype that identifies the levels of noise pollution, providing a starting point and reference, based on the identification of the thoughts and needs of the client and/or user, which led to the development of the research work.

It was possible to design a low-cost prototype for the measurement of noise pollution levels, using cheap and easily available electronic components on the market, identifying important factors for its development, such as the proper selection of the sensor, since some of the they pick up a lot of noise coming from the power supply, affecting the measurements; In addition, the use of open source platforms based on free software was used, adapted to the needs of the project.

The development of a mobile application called Acoustic Level was achieved, developed for Android mobile devices, for its operating system versions higher than 6.0 (Mashmallow), requiring a minimum memory space of 31.83 MB, in which it is displayed, using a graph, the real-time measurements of the level of noise pollution, for example, through the application and the measurements made during 9:11 a.m. and 6:31 p.m., on February 11, 2022, it was possible to deduce that the average level of noise pollution was 61.48 dB and that, in the measurements made in the morning hours were the ones that had the highest levels of contamination, being the data of 11:01 A.M., the one that obtained the highest peak with 78,519 dB, apparently, the noise generated by the flow of traffic, is the triggering agent of these levels.

Finally, and using the descriptive survey as a measurement instrument, the excellent level of acceptance and satisfaction that the research project had is evident, in addition to enhancing the interest of people in the environment by wanting to monitor and control the various types of contamination, environmental issues, especially acoustics, the truth is, we are the main generating agents, therefore, the solution is also in our hands.

It is recommended to continue with this type of research on noise pollution, because it is an invisible enemy for the mental, psychological and physiological health of people, its monitoring and control is of utmost environmental importance.

This type of prototypes and applications can be used in different spaces of community interest such as: libraries, hospitals, museums, airports, auditoriums, etc., and even in discos or concerts, in order to avoid temporary or permanent hearing damage, due to exposure times to high noise levels.

As an opportunity to improve this research project, another series of sensors can be integrated into the development board, such as sensors for gas measurement, temperature and humidity sensors, among others, and integrated into the application, in addition to being able to use a module for simcard in order to upload data to it and avoid being dependent on a Wi-Fi service, it could also integrate a GPS module to be recovered in case of theft.

These types of applications could also be used by control entities for environmental monitoring, so that when the noise level exceeds the allowable level, an alert is sent, which would help decision-making and action.

References

[1] J. Khan, M. Ketzel, K. Kakosimos, M. Sørensen & S. Jensen,"Road traffic air and noise pollution exposure assessment–Areview of tools and techniques," *Sci Total Environ*, vol. 634, pp. 661–676, Sep. 2018. https://doi.org/10.1016/j.scitotenv.2018.03.374

[2] A. Gupta, A. Gupta, K. Jain & S. Gupta,"Noise pollution and impact on children health," *Indian J Pediatr*, vol. 85, no. 4, pp. 300–306, Jan. 2018. https://doi.org/10.1007/s12098-017-2579-7

[3] T. Münzel, M. Sørensen & A. Daiber,"Transportation noise pollution and cardiovascular disease," *Nat. Rev. Cardiol.*, vol. 18, no. 9, pp. 619–636, Mar. 2021. https://doi.org/10.1038/s41569-021-00532-5

[4] J. Ma, C. Li, M. Kwan & Y. Chai, "A multilevel analysis of perceived noise pollution, geographic contexts and mentalhealth in Beijing," *Int J Environ Res Public Health*, vol. 15, no. 7, pp. 1–18, Jul. 2018. https://doi.org/10.3390/ijerph15071479

[5] S. Ismail & S. Ahmed, "Noise pollution, its sources and effects: A Case study of University students in Delhi," *EPRA-IJEBR*, vol. 6, no. 2, pp. B15–B23, Feb. 2018. https://ssrn.com/abstract=3149388

[6] A. Oluwatayo, J. Omoijiade, O. Oluwole, F. Okubote, O.Eghobamien & A. Gbwefi, "Effectiveness and Sustainability of Acoustic Measures in Palms Mall, Ota," presented at *Conference Series: Materials Science and Engineering*, IOP, OTA, NG, 10-14 Aug. 2020. https://doi.org/10.1088/1757-899X/1107/1/012208

[7] M. Celestina, J. Hrovat & C. Kardous,"Smartphone-based sound level measurement apps: Evaluation of compliance with international sound level meter standards," *Appl Acoust*, vol. 139, pp. 119–128, Oct. 2018. https://doi.org/10.1016/j.apacoust.2018.04.011

[8] Y. Liu, X. Ma, L. Shu, Q. Yang, Y. Zhang, Z. Huo & Z.Zhou, "Internet of things for noise mapping in smart cities: state of the art and future directions," *IEEE Netw*, vol. 34, no. 4, pp. 112–118, Jun. 2020. https://doi.org/10.1109/MNET.011.1900634

[9] L. Martín, "Contaminación acústica: la amenaza invisible," *hazrevista*, Ago. 2017. Disponible en https://hazrevista.org/rsc/2017/08/contaminacion-acustica-la-amenaza-invisible/

[10] A. Ramírez & E. Domínguez, "Modeling urban traffic noisewith stochastic and deterministic traffic models," *Appl Acoust*, vol. 74, no. 4, pp. 614–621, Aug. 2012, https://doi.org/10.1016/j.apacoust.2012.08.001

[11] L. Sánchez, L. Sánchez, J. Carbajal & L. Pérez,"Methods of analysis for urban environmentalnoise," presented at *SAI Intelligent Systems Conference*, IntelliSys, LDN, UK, 10-11 Nov. 2015. https://doi.org/10.1109/IntelliSys.2015.7361170

[12] A. Garrido, Y. Camargo, y A. Vélez-Pereira, "Nivel continuo equivalente deruido en la unidad de cuidado intensivoneonatal asociado al síndrome de burnout," *Enferm Intensiva*, vol. 26, no. 3, pp. 92–100, Mar. 2015. https://doi.org/10.1016/j.enfi.2015.03.002

[13] A. Garrido, Y. Camargo, y A. Vélez-Pereira, "Nivel de ruido en unidades de cuidado intensivo de un hospital público universitario en Santa Marta (Colombia)", *Med Intensiva*, vol. 40, no. 7, pp. 403–410, Oct. 2016. https://doi.org/10.1016/j.medin.2015.11.011

[14] P. Velásquez, L. Vásquez, C. Correa & D. Rivera, "A low-cost IoT based environmental monitoring system. A citizen approach to pollution awareness," presented at *2017 CHILEAN Conference on Electrical, ElectronicsEngineering, Information and CommunicationTechnologies*, CHILECON, PCN, CL, 18-20 Oct. 2017. https://doi.org/10.1109/CHILECON.2017.8229599

[15] P. Páramo, "Reglas proambientales: una alternativa paradisminuir la brecha entre el decir-hacer en la educación ambiental", *Suma Psicol*, vol. 24, no. 1, pp. 42–58, Nov. 2016. https://doi.org/10.1016/j.sumpsi.2016.11.001

[16] L. Bravo-Moncayo, M. Chávez, V. Puyana, J. Lucio-Naranjo, C. Garzón & I. Pavón-García, "A cost-effective approach to the evaluation of traffic noise exposure in thecity of Quito, Ecuador," *Case Stud Transp Policy*, vol. 7, no. 1, pp. 128–137, Dec. 2018. https://doi.org/10.1016/j.cstp.2018.12.006

[17] S. Pal, A. Ghosh & V. Sethi, "Vehicle Air Pollution Monitoring Using IoTs," presented at *16th ACM Conference on Embedded Networked Sensor Systems*, ACM, SZ, CN, 4-7 Nov. 2018. https://doi.org/10.1145/3274783.3275202

[18] C. Ordoñez, J. López, H. Guañarita & J. Ordoñez, "Monitoring and analysis of air quality for community empowerment in Environmental Health," *J Phys Conf Ser*, vol. 1247, no. 1, pp. 1–9, Jun. 2019. https://doi.org/10.1088/1742-6596/1247/1/012054

[19] N. Ramirez, D. Contreras, L. Padilla & R. Montelongo, "Acoustic Contamination and its Effects on the Heart Rate and Mood," presented at *2018 15th International Conference on Electrical Engineering, Computing Science and Automatic Control*, CCE, CDMX, MX, 5-7 Sep. 2018. https://doi.org/10.1109/ICEEE.2018.8533954

[20] C. Rojo y D. Girbau, "Diseño de un sonómetro con conexión WiFi para el control de nivel de sonido", *Trabajo de Grado*, ITEM, ETSE, UV, VC, ES, 2017. Recuperado de http://deeea.urv.cat/public/PROPOSTES/pub/pdf/2495res.pdf

[21] J. Liedtka, "Why design thinking works," *Harv Bus Rev*, vol. 96, no. 5, pp. 72–79, Sep. 2018. Available: https://hbr.org/2018/09/why-design-thinking-works

[22] R. Dias, D. Costa, H. Correia & C. Costa, "Building Bio-Districts or Eco-Regions: Participative Processes Supported by Focal Groups," *Agriculture*, vol. 11, no. 6, pp. 1–14, May. 2021. https://doi.org/10.3390/agriculture11060511

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