DOI: 10.61782/fa.2025.0292

FORUM ACUSTICUM EURONOISE 2025

DEVELOPMENT OF A TOOL FOR NOISE MANAGEMENT IN LEZs

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ABSTRACT

Audiotec is part of a consortium that is carrying out an R&D project with the overall objective of developing a comprehensive and accessible prototype to assist decision-makers in the fight against climate change and air pollution in the task of defining and assessing the economic, social and environmental impact of Low Emission Zones (LEZs) in urban areas.

Audiotec's role in the project is the development of a non-standardized tool for environmental noise prediction in LEZs using geographic information systems (GIS).

The developed tool, which is easy to use, allows to quickly predict the evolution of acoustic indices and health indicators in LEZs, as well as to analyze the acoustic impact in these areas in different alternative scenarios, varying the mobility parameters.

The developed prototype presented here allows municipal technicians to manage LEZs through the use of commonly used free software, with the consequent saving of resources.

Keywords: Low Emission Zones, acoustic module, noise map.

1. INTRODUCTION

The Spanish Law on Climate Change and Energy Transition defines a LEZ as 'an area delimited by a public administration, in the exercise of its powers, within its territory, of a continuous nature, and in which restrictions on access, circulation and parking of vehicles are applied to improve air quality and mitigate greenhouse gas emissions, according to the classification of vehicles by their level of emissions in accordance with the provisions of the General Vehicle Regulations in force'.

Low Emission Zones are a mobility management tool that helps to promote a modal shift in cities towards more sustainable modes of transport, as well as the adoption of low-emission alternative vehicles, such as electric cars.

Spanish municipalities are currently in the process of implementing LEZs, and there is a need for public administrations to have tools that facilitate the definition of their boundaries and perimeter, the analysis of emission reductions, and access to information on public health, as well as economic and social aspects.

In this context, in 2024, an R&D project was proposed in collaboration with several companies, with the overall objective of developing a comprehensive and accessible prototype that would assist decision-makers in the fight against climate change and air pollution by facilitating the task of defining and evaluating the economic, social, and environmental impacts of Low Emission Zones (LEZs) in urban areas. The aim was to promote more effective and sustainable management of urban mobility, in line with the objectives of reducing pollutant emissions and improving air quality, as established in regulatory frameworks at all levels (local, regional, national, and European). At the same time, it aimed to provide additional benefits for the locality and its citizens, such as reducing noise pollution, improving health and quality of life, promoting alternative forms of mobility (sustainable mobility), and creating healthier and more livable urban spaces; see Fig. 1.

- To analyze and diagnose the starting point by calculating the current balance of carbon and pollutant emissions in the municipality through the integration of data from public and private sources. Among other sources of information, noise maps are used to

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identify not only sources of noise pollution but also atmospheric pollution, as these often overlap.

- Design the LEZ by defining its area, extension and perimeter, as well as the number of LEZs in the city being studied.
- Evaluate and visualize the potential impacts and changes that the LEZ causes in the carbon balance and pollutant emissions in the municipality (CO, NO, NO2, O3, PM10, PM2.5, SO2).
- Quantify other impacts and benefits (economic, social and environmental) that the defined LEZ could potentially produce.
- Evaluate the different options (scenarios) by calculating indicators that enable quantitative comparison and support informed decision-making.
- Export the results for the scenario identified as optimal.

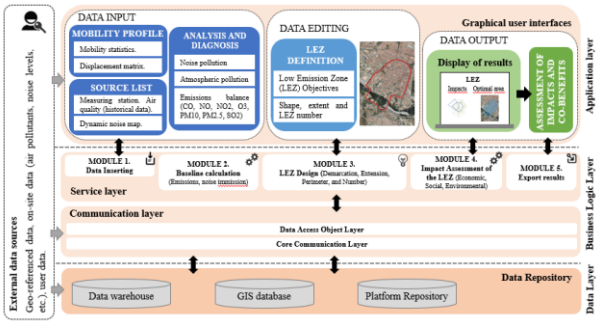

Figure 1. Conceptual framework and functional modules of the platform prototype

Audiotec's role in this R&D project has focused on the development of the acoustic module of the platform.

2. NEED FOR THE DEVELOPED TOOL

Currently, municipalities with more than 100.000 inhabitants are required to update and approve the strategic noise maps for their territory, along with the corresponding action plans.

Strategic noise maps are a valuable tool for assessing the acoustic environment of a municipality with respect to environmental noise and for developing, based on the graphical and statistical results they provide, well-founded action plans to address noise pollution. However, updating these maps requires considerable effort and the use of specialized software for environmental noise prediction, which makes it challenging for government technicians to perform frequent updates.

In this context, Audiotec has developed a module for the acoustic assessment of LEZs with the following objectives:

- To thoroughly research and analyze the specific characteristics and needs of the city regarding the implementation and management of Low Emission Zones (LEZ), considering environmental noise as a key factor.
- Design and develop an automated, intuitive, and easily accessible prototype that enables decision-makers (consultants, urban planners, politicians, etc.) to visualize and analyze the 'noise' variable when defining the area and impact of the LEZ.
- Develop algorithms and models to assess the potential impact of implementing or expanding of an LEZ in terms of noise reduction.
- Integrate Geographic Information Systems (GIS) based calculation capabilities, up-to-date databases and public information sources on noise and mobility to ensure the accuracy and reliability of the data used in developing of the acoustic module.
- Conduct a pilot test to validate the results in collaboration with local authorities and other relevant stakeholders to ensure the practical utility, acceptability, and adaptability of the acoustic module in various urban contexts.

3. DESCRIPTION OF ACOUSTIC MODULE

This is a prototype developed to assess and compare the acoustic impact of various traffic management measures in Low Emission Zones (LEZ). The tool allows users to edit and update the parameters related to traffic in the different streets within the LEZ. Using an intuitive interface in QGIS, users can select a specific road by name and modify key data such as traffic volume, speed, and road surface type. These changes are applied to a new layer that duplicates the original, ensuring that the previous data is preserved and enabling direct comparisons.

Additionally, the tool includes a feature that allows for the calculation of noise levels that receptors will experience after the implementation of the new conditions. As a result, a new receptor layer is generated with the updated values, facilitating the analysis of the acoustic impact of the introduced changes; see Fig. 2.

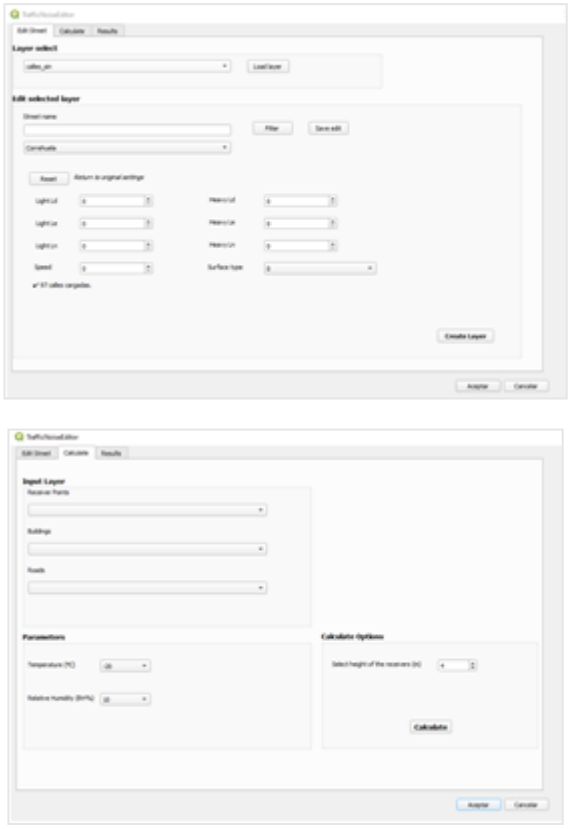

Figure 2. Prototype Model.

It should be noted that these calculations do not account for factors such as the topography of the terrain or the acoustic absorption properties of various urban elements. Furthermore, the search radius for assigning values to receptors is limited to 50 meters. However, in the context of Low Emission Zones, where the analysis focuses on small areas, this approach is sufficiently valid to support decision-making. These simplifications enable faster processing times and dynamic visualization of the effects of the proposed measures, facilitating a quick and effective assessment of their impact on urban noise pollution.

In addition, the tool has been designed with an adaptive approach that allows it to be adapted to the specific characteristics of each city. This enables it to be configured to accommodate different types of road infrastructure, analysis criteria, and local regulations, offering a flexible solution for planning noise mitigation strategies in LEZ environments.

As a prototype, the tool is in the initial development phase and can be refined and adapted in the future based on emerging needs and methodological advancements.

Being developed in QGIS environment, this tool leverages the full range of benefits offered by this open-source software, including its visualization and geospatial analysis capabilities. Users can overlay multiple layers of information, perform spatial queries, and combine results with other environmental or urban data available within the project. This enables a more comprehensive interpretation of the impact of the measures implemented and facilitates the integration of acoustic variables into urban planning processes. Furthermore, as part of the QGIS ecosystem, the tool is compatible with a wide variety of data formats and can be easily adapted to meet the specific needs of each city, ensuring its applicability across diverse urban contexts.

One of the key advantages of this tool is its accessibility for users who are not familiar with the QGIS environment. Thanks to its intuitive interface, no advanced knowledge of geospatial editing methods is required to modify traffic parameters. Users can quickly make adjustments through the integrated questionnaire, enabling them to incorporate changes such as traffic volume, speed, or pavement type with ease. This ease of use broadens the tool's accessibility to a wider audience, including urban planners, local authorities, and other non-technical users, empowering them to make informed decisions without the need for specialized GIS expertise.

4. PROTOTYPE VALIDATION PILOT TEST.

In 2023, Audiotec was responsible for updating the fourth-phase of the strategic noise map and action plan in the city of Salamanca, a municipality in Castilla y León (Spain) with a population of over 140,000 inhabitants.

During the duration of the Noise Action Plans, the Low Emission Zone is expected to be implemented.

The Low Emission Zone, expected to have a highly beneficial impact on environmental noise, is designed as a ring system, given that Salamanca is a radial city with its epicenter at Plaza Mayor, the city's geographic and cultural hub.

The first of the rings encompasses an area of approximately 600 000 m², which is being fully pedestrianized. It merges

areas that previously contained intermediate corridors and adds new streets and squares that were once designated for unrestricted motor vehicle movement. All access points to this area will be monitored by cameras equipped with license plate recognition.

Figure 3. Pedestrian area.

The second perimeter shares its northern boundary with the first and spans approximately 1 500 000 m²; it encompasses the entire first ring road of the city, along with both banks of the River Tormes. This area includes all the monuments that contributed to Salamanca being designated a UNESCO World Heritage City, making it essential to protect the health of its inhabitants.

Figure 4. Low Emission Zone (ZLE) area.

The Low Emission Zone (LEZ) of Salamanca has been selected to test and validate the developed acoustic module. This decision is based on the availability of sufficient cartographic and demographic data to feed the model, as well as the existence of previous results obtained using the commercial software CadnaA. A comparison was then made between the model generated with CadnaA and the prototype acoustic tool developed.

The analyzed area of the LEZ has a population of 14 665 inhabitants. The evaluation enables the analysis of differences in the estimation of environmental noise impact and health indicators for the population, as well as the verification of the prototype's usefulness in the acoustic management of these areas. It is important to note that the prototype is not intended to be standardized software, but rather an analytical tool whose results should be interpreted relatively, rather than absolutely. Its goal is to provide an accessible tool for municipal technicians responsible for managing Low Emission Zones (LEZ), enabling them to evaluate alternative scenarios using free and commonly available software.

4.1 Analysis of acoustic receivers in façades

When comparing the estimated values at the receptors on the façades of both models for a typical building in the LEZ, it can be observed that the model generated with CadnaA presents slightly higher noise levels on certain façades, particularly in areas with greater exposure to traffic.

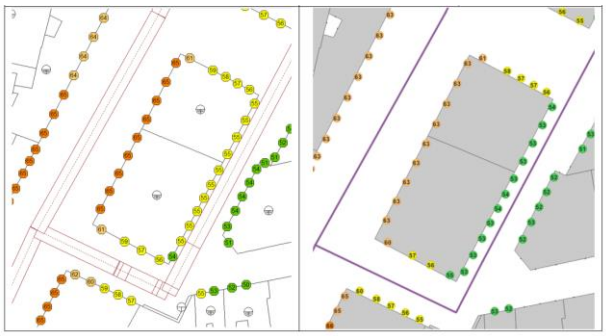

Figure 5. Noise levels in facade. CadnaA model on the left and GIS model on the right.

The maximum difference between the two models is approximately 2 dBA.

The following graphs display the distribution of the percentage of receivers as a function of the acoustic index value within the range of 55 to 69 dBA for three time periods (day, evening, and night) in the analyzed LEZ. Each graph compares the values obtained using the

commercial software CadnaA with those from the developed acoustic prototype, see Fig.6.

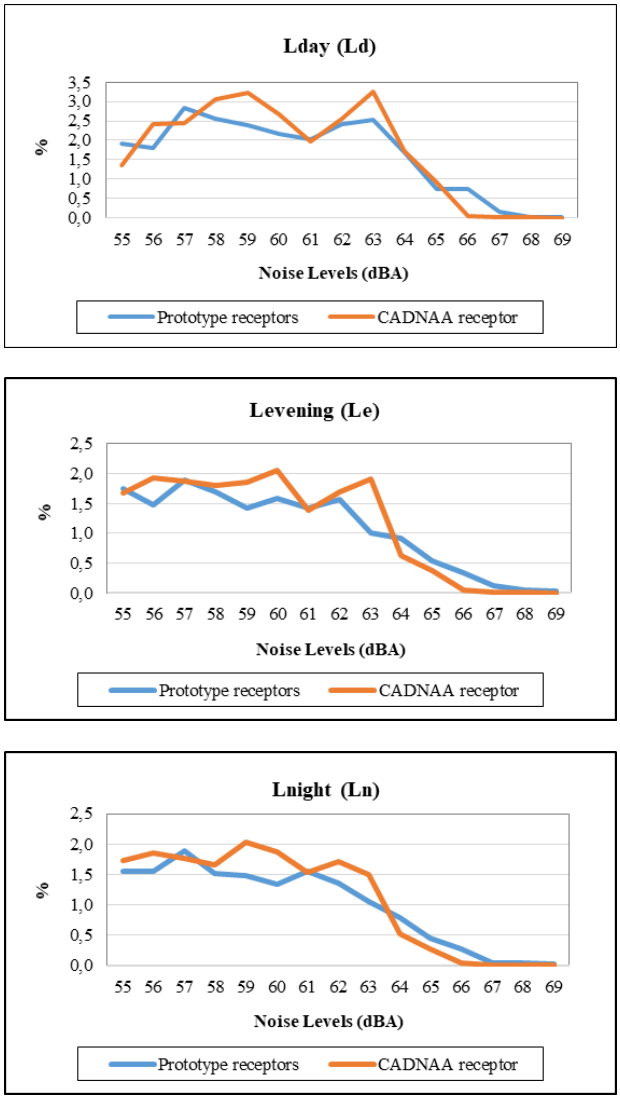

Figure 6. Distribution of the percentage of receptors across three time periods (day, evening, and night) in the analyzed Low Emission Zone (LEZ).

In all three time periods, the distribution of the percentage of receptors is similar in both models.
It is observed that the maximum number of receptors occurs at intermediate values, followed by a gradual decrease as the noise level increases.

The developed acoustic prototype shows significant agreement with the results obtained using CadnaA, with differences falling within an acceptable range for decision-making in the management of the LEZ.

4.2 Analysis of the population impacted by environmental noise

In the evaluated Low Emission Zone (LEZ), the results for the number of people and the percentage of the population exposed to noise, as estimated by both methods, have been compared across the different acoustic indicators, see Table 1:

Table 1. Population exposed to noise.

Acoustic Indicator	CadnaA		Prototype	
	Number of people	% population	Number of people	% population
Ld > 65 dBA	215	1.47%	374	2.56%
Le > 65 dBA	229	1.57%	371	2.53%
Ln > 55 dBA	2596	17.70%	2538	17.31%

The results indicate that, although the values estimated by both methods are similar, the prototype estimates a higher number of people affected during the daytime (Ld) and evening (Le) periods compared to the CadnaA software, while the differences are smaller during the nighttime (Ln) periods.

The Ln indicator has been chosen as the reference to study the distribution of people by ranks and the percentages of the population exposed to noise. The results obtained are as follows, see Table 2:

Table 2. Population exposed to noise based on the Ln indicator.

Nighttime noise level range (Ln, dBA)	CadnaA		Prototype	
	Number of people	% population	Number of people	% population
50 < Ln ≤ 55	2897	19.75%	2550	17.39%
55 < Ln ≤ 60	2433	16.60%	2238	15.26%
60 < Ln ≤ 65	163	1.10%	300	2.05%
Ln > 65	0	0%	0	0%

It is observed that both models provide similar estimates; however, the acoustic tool prototype, compared to CadnaA, predicts lower impairment in the 50-55 dBA

and 55-60 dBA ranges, but higher impairment in the 60-65 dBA range.

4.3 Analysis of health indicators related to environmental noise

In addition to acoustic information, the prototype enables the calculation of health indicators related to noise exposure. The results obtained are presented below, see Table 3:

Table 3. Population exposed to noise according to health indicator.

Health Indicator	CadnaA		Prototype	
	Number of people	% population	Number of people	% population
Nxy_ECI	180	0.82%	180	0.82%
Nxy_MI	1385	6.28%	1341	6.08%
Nxy_AGS	287	1.30%	275	1.25%

The estimated values of the health indicators obtained using the prototype are very similar to those obtained using CadnaA.

5. CONCLUSIONS

As part of an R&D project aimed at developing a comprehensive and accessible prototype to assist decision-makers in defining and assessing the economic, social, and environmental impacts of Low Emission Zones (LEZs) in urban areas, Audiotec has developed a module that enables the assessment of environmental noise in LEZs.

The acoustic module has been developed based on the Common Noise Assessment Methods in Europe (CNOSSOS-EU) for road traffic noise, although certain simplifications have been made to the methodology to enhance its agility and operational efficiency, as well as to expand its use to operators working with open-source software.

A pilot test has been conducted to validate the module in the LEZ of the city of Salamanca by comparing the results obtained from the acoustic module with those estimated in the municipality's strategic noise map. The differences between the two methods are not significant, and it can be concluded that the developed acoustic module provides reliable information.

The acoustic module offers several advantages over standard commercial programs for environmental noise prediction, including reduced processing times, ease of use, strong dynamic visualization capabilities for the effects of proposed measures, and quick, effective evaluation of noise-related health indicators and the impact of noise pollution in LEZ.

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