TÍTULO

ENVIRONMENTAL NOISE EVALUATION PRODUCED BY ROAD TRAFFIC IN ONE OF THE MOST POPULATED NEIGHBORHOODS OF VALENCIA, SPAIN

AUTOR

Jonathan Patricio Gordillo Urresta

Esta edición electrónica ha sido realizada en 2021

Director	Dr. D. Rafael Sánchez Sánchez
Instituciones	Universidad Internacional de Andalucía ; Universidad de Huelva
Curso	*Máster Oficial Interuniversitario en Tecnología Ambiental (2020/21)*
©	Jonathan Patricio Gordillo Urresta
©	De esta edición: Universidad Internacional de Andalucía
Fecha documento	2021

un
Universidad
Internacional
de Andalucía
A

ENVIRONMENTAL NOISE EVALUATION PRODUCED BY ROAD TRAFFIC IN ONE OF THE MOST POPULATED NEIGHBORHOODS OF VALENCIA, SPAIN

Jonathan Patricio Gordillo Urresta

Trabajo entregado para la obtención del grado en **MASTER EN TECNOLOGÍA AMBIENTAL**

Modalidad: Investigación

Diciembre / 2021

Director:

Dr. Rafael Sánchez Sánchez

RESUMEN

Diversos organismos oficiales como la Agencia Europea de Medio Ambiente (AEMA) declaran que la salud de las personas se ve seriamente afectada por el ruido tanto a nivel fisiológico como psicológico. Esta misma agencia revela que una de las principales fuentes de ruido es el tráfico rodado, sobre todo en grandes ciudades como Madrid o Barcelona. En 2018, el Ayuntamiento de Valencia tomó como medida mitigadora reducir la movilidad vehicular en el Casco Antiguo de la ciudad. Sin embargo, distintas asociaciones de vecinos de Valencia declaran que esta medida ha desplazado el tráfico hacia otras barriadas. Además, según reflejan los últimos datos publicados en el portal estadístico del Ayuntamiento de Valencia, los niveles de ruido generados en zonas residenciales que rodean el Casco Antiguo de Valencia superan ampliamente los límites establecidos por la AEMA. Este problema ha sido muy acusado en el barrio de Ruzafa debido a las continuas quejas que han presentado sus habitantes. Por esta razón, el presente estudio abordará el análisis de los niveles de presión sonora de este, uno de los barrios más afectados por la contaminación acústica de tráfico rodado, así como también, el análisis de sus consecuencias con la normativa legal vigente. La evaluación de la contaminación acústica se realizará a través de la digitalización del terreno y toda su urbanística, con el objetivo de presentar los niveles acústicos de la zona mediante un modelo de predicción acústica para el que se utilizará el software CadnaA. Además, se añadirá un modelo geoestadístico para analizar el área y el número de personas afectadas. Finalmente, se procederá a la validación del modelo a través de la correlación con medidas in situ realizadas por las estaciones de monitoreo del Ayuntamiento de Valencia, para concluir con la creación de un Mapa Estratégico de Ruido del barrio de Ruzafa.

ABSTRACT

Several official agencies such as the European Environment Agency (EEA) declare that the health of people is seriously affected by noise both physiologically and psychologically. This same agency reveals that one of the main sources of noise is road traffic, especially in large cities like Madrid or Barcelona. In 2018, the City Council of Valencia took as a mitigating measure reduce vehicular mobility in the historical center of the city. However, different neighborhood associations of Valencia declare that this measure has displaced traffic to another neighborhoods. In addition, according to the latest data published in the Statistical Portal of Valencia City Council, noise levels generated in residential areas surrounding the historical center of Valencia far exceed the limits established by EEA. This problem has been very accused in the Ruzafa neighborhood due to the continuous complaints that have presented its inhabitants. For this reason, this study will address the analysis of the sound pressure levels of this, one of the neighborhoods most affected by the acoustic contamination of road traffic, as well as, the analysis of its consequences with the current legal regulations. The evaluation of acoustic contamination will be performed through the digitization of the terrain and its entire urbanistic, with the aim of presenting the acoustic levels of the area through an acoustic prediction model for which CadnaA software will be used. In addition, a geostatistical model will be added to analyze the surface and the number of people affected. Finally, the model will be validated through the correlation with on-site measures carried out by the sound monitoring stations of Valencia City Council, to conclude with the creation of a strategic noise map of Ruzafa neighborhood.

INDEX

RESUMEN v
ABSTRACT vi
CHAPTER 1. INTRODUCTION 1
1.1. Acoustic contamination 2
1.1.1. Weighting networks 2
1.1.2. Noise sources 3
1.2. Effects on health and well-being 5
1.3. Normative and Acoustic Legislation 6
1.3.1. National Legislation 6
1.3.2. Autonomic Legislation 8
1.3.3. Local legislation 9
1.4. Municipal context of the study zone 9
1.5. Objectives 11
CHAPTER 2. MATERIALS AND METHODS 13
2.1. Study zone 13
2.2. Materials 15
2.2.1 Noise indexes used in acoustic contamination 16
2.2.2. Data frame acquisition 18
2.2.3. Time series data format and quality control 19
2.3. Methods 21
2.3.1. Digitization process 21
2.3.2. Configuration of the roads structure 23
2.3.3. Configuration of the buildings structure 24
2.3.4. Setting up calculation and mesh 25
2.3.5. Geoprocessing model to evaluate the exposure to noise 25
CHAPTER 3. RESULTS AND DISCUSSION 27
3.1. Validation of the acoustic model 27
3.2. Ruzafa noise maps 30
3.3. Diagnosis of noise exposure levels according to the policy framework 36
3.3.1 Study zone SZ1 36
3.3.2. Study zone SZ2 37

3.3.3. Study zone SZ3 38
3.4. Analysis of the acoustic sensitive areas 39
3.5. Estimation of the percentage of highly annoying people by traffic noise 40
CHAPTER 4. CONCLUSION 43
BIBLIOGRAPHY 45
ANNEXES 49

CHAPTER 1. INTRODUCTION

Numerous studies conducted in recent years by European Administrations have concluded that noise pollution is a phenomenon that seriously affects human health (World Health Organization, 2018). Due to the large number of inhabitants exposed to excessively high noise levels, a series of prevention, control and reduction measures have been proposed by these government institutions. As one of the main sources of environmental contamination, urban traffic noise has the ability to cause human diseases. According to Münzel et al. (2018), noise from urban traffic has the ability to cause human diseases, such as atrial fibrillation, diabetes, and high blood pressure. For this reason, to study the intensity of traffic noise in order to evaluate the magnitude of exposed population are fundamental to manage the acoustic pollution.

By the other hand, transportation network is a main component for the society, because it facilitates the necessary infrastructure to promote the correct mobility and accessibility of population. Irretrievably, the continuous expansion of transportation network in the last decades also implies an increase in the rate of environmental pollution. Precisely, one of the main problems in Valencia (Spain) is the acoustic contamination that result from road traffic (Ajuntament de València, 2017).

Due to all this, the Valencia City Council has stated that the historical center as a residential priority area, applying measures to restrict access, circulation and vehicle parking to non-residents with the aim of preserving the sustainable use of the roads, as well as, reducing the levels of acoustic and atmospheric contamination (Ajuntament de València, 2020). With the urbanistic reform performed in the center of the city, it was tried to mitigate the affection of road traffic, among other things. However, these changes could have led an increase in traffic levels on the roads that surround the historical center, such as the large roads located in the Ruzafa neighborhood. Nowadays, noise pollution complaints represent a large percentage of environmental problems in this neighborhood. According to the latest report from the Council's Complaints and Suggestions Office, in just one year the registered complaints have increased by 81,94%, from 648 to 1179 (Ajuntament de València, 2019). This report also shows that more than half of the complaints, specifically 591, are caused by traffic noise that include the public transportation.

Currently, Ruzafa neighborhood lives a process of urban transformation through building rehabilitation, that has caused the growth of housing which entails an increase in the population. In addition, Ruzafa is one of the oldest neighborhoods in Valencia marking a suitable place for tourist influx. Because of this, the vehicle activity has skyrocketed and with it the concern of the inhabitants by keeping the neighborhood within acoustic limits. Due to the continuous complaints, the City Council of Valencia proposed to place an acoustic monitoring network with the aim of recording the noise sources that generate excessive sound levels in Ruzafa. This network has located the sonometers in strategic points of the neighborhood 4 meters from the ground. Thus, this study will make use of the measurements of noise stations to carry out the evaluation of the current environmental acoustic contamination that is generated in one of the most densely populated neighborhoods in Valencia, affecting around 23826 inhabitants.

1.1. Acoustic contamination

According to the Noise Law 37/2003, acoustic contamination is defined as "*the presence of noises or vibrations in the environment, whatever the acoustic issuer that originates them, that involve discomfort, risk or damage for people, for the development of their activities, even when its effect is to disturb the enjoyment of natural sources, or cause significant effects on the environment*". Thus, noise could be considered an annoying or unwanted sound, which can be evaluated from two approaches. From an objective point of view, noise is a phenomenon characterized by certain parameters like: wavelength, frequency components and energy, among others. However, from a subjective point of view as it happens in psychoacoustics, noise depends on the perception of an individual which implies personal considerations about what sound is annoying for each person. Besides to causing discomfort, noise can cause health damage which can be irreversible, therefore is considered a non-fatal work risk (Recio et al., 2016).

1.1.1. Weighting networks

The frequency analysis of a measured noise is fundamental since the same level of sound pressure can represent very different frequency distributions, being more annoying when increasing the high frequency component. The human ear is most sensitive to frequencies between 500Hz and 6kHz and are less sensitive to frequencies above and below these. For this reason, filters were prepared to better represent the perceived noise level. In order to estimate the different human responses against a noise depending on the frequency spectrum, the concept of standard weighting curves was introduced. These curves discriminate the relative weight of each frequency in the spectrum assembly (Kinsler et al., 2000).

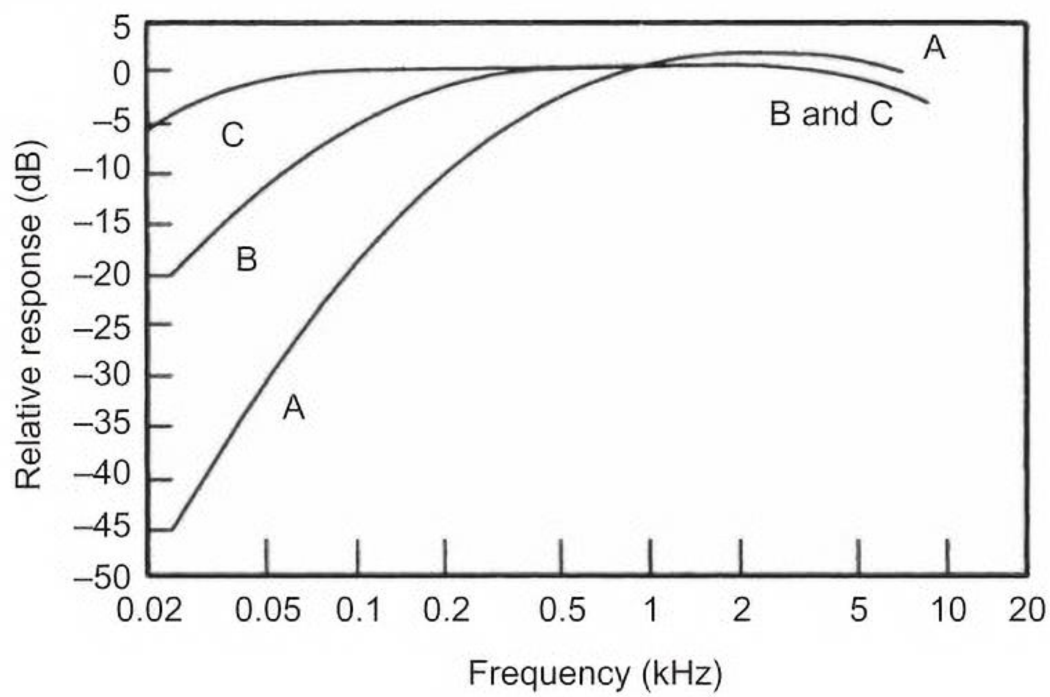


Figure 1. Frequency weighting curves (Martyr & Rogers, 2021).

In order to approach the ear response, have been created the frequency weighting curves which are a simplification of the frequency response of the human ear at different levels (Figure 1). Thus, for low levels of sound pressure, the A-weighting curve is used, since it attenuates a lot the low frequencies (-50 dB at 20 Hz and almost -20 dB at 100 Hz) and to a lesser amount the high frequencies (almost -10 dB in 20 kHz). The A-weighting curve is suitable for the measurement of background noises, which is considered the low sensitivity hearing curve. Consequently, this curve is used to express the subjective intensity of sound for the human ear, which is a standardized unit of measurement to quantify the noise caused by transport. When the decibels values are expressed in this measure, the dB(A) denomination is adopted. Moreover, the B-weighting curve is used for intermediate levels of sensitivity, but currently this weighting curve is disused. Finally, the C-weighting curve is approaching the hearing curve of high sensitivity since it barely provides attenuation of low frequencies.

1.1.2. Noise sources

The noise can be generated by natural or artificial sources. Natural sources of noise are those produced by elements of nature such as rain, storms, volcanic eruptions and sounds produced by animals, among others. On the other hand, artificial sources are those produced by objects created by the human being and can be classified into punctual and linear sources. Both, punctual and linear sources will maintain their direction of propagation until touch the terrain obstacles such as building, vegetation, orography, among others.

- **Punctual source** is a small noise source compared to the distance to the listener. The punctual source radiates spherical waves by conducting an equally sound propagation in all directions and the level decreases in 6 dB when duplicating the distance. Spherical propagation is the most common way to represent this behavior, however this should not be associated with the formation of a perfect sphere. Also, it can adopt another type of forms such as pseudo elliptic behavior due to the influence of other factors (Möser & Barros, 2009).
- **Linear sources** are those that emit sound along an imaginary line called axis. For this reason, a vehicle can be considered as a linear source if its speed is greater than 30 km/h, at lower speed it is more accurate to consider it punctual source (Datakustic, 2005). The propagation occurs in the radial directions, so that the sound pressure level is the same at all points of the line and decreases in 3 dB when duplicating the distance (Möser & Barros, 2009). It is noteworthy that the sound coming from a linear source comes much farther than the one that emanates from a punctual source (Möser & Barros, 2009).

In acoustic pollution, road traffic is one of its greatest problems since it is the most widespread and affects especially in urban areas. Basically, this type of noise is caused by engine noise including exhaust and intake noise that vehicles provide under speeds below 50 km/h, along with tyre-road noise which dominates the car exterior noise generated at higher speeds, which are usually greater than 70 km/h (Kumbhar et al, 2014). Due to the great influx of traffic in urbanized areas, rolled transport vehicles, which pass through large streets, avenues and highways will be considered linear noise sources. This feature facilitates its study through predictive software that allow to evaluate their behavior reliably by taking representative experimental samples. In this way, it is possible to visualize energy averages, which prevents having to monitor the current state of real-time noise. Since road traffic noise in this urban study zone is the predominant about other sources, it will be considered in the NM.

The continuous variations of the sound level produced by road traffic are largely due to their random behavior, which is directly related to three factors of influence. First, the characteristics of the vehicle influence the sound levels due to its mechanical structure and its state of conservation (Morales, 2009). Second, it has been investigated that each person's driving style is directly related to the fluctuation of decibels (Ramos et al., 2012). Third, the state of the surface road (slope and composition), and to a lesser extent, the atmospheric conditions (temperature and humidity) inflate at the sound level produced by road traffic (Morales, 2009).

Traffic fluency is one of the requirements that are assigned to develop the calculation methodologies of interurban traffic noise levels. This fluency represents the displacement of vehicles without interruptions on its movement, so that there are no accelerations and stops which would force vehicles to reduce speed and move on short gears.

- In the **fluid continuous flow**, vehicles move at almost constant speed through the linear road segment. The flow is stable both in space and time during periods of at least ten minutes (Datakustic, 2005). Variations can be produced in the course of a day, but these should not be abrupt or rhythmic. In addition, the flow is not accelerated or decelerated, but it registers constant speed. This type of flow corresponds to the traffic of highways, interurban roads and large roads of urban environments.
- In **continuous flow in pulses**, the proportion of vehicles in transition is significant, there are sudden variations of the flow in short periods of time and irregular concentrations of vehicles are produced in the section of the road. However, it is still possible to define an average speed for this type of flow, which is stable and repetitive for a sufficiently long period of time (Datakustic, 2005). This type of flow corresponds to the streets of urban centers, important pathways that are close to saturation, connection and distribution routes with numerous intersections, parking, pedestrian steps and access to housing areas.

1.2. Effects on health and well-being

To evaluate the noise impact, the acoustic parameters must be considered in relation to their biological and psychological translation in people. On this way, the possibility that environmental noise causes negative effects on human health, has greatly stimulated investigations in this field, so that most studies have focused on knowing what are the levels of acoustic contamination of the environment and to what extent they affect the health and well-being of people.

Acoustic environmental degradation can influence the health and well-being of individuals, which is why it has promoted investigations. The results of them have allowed to know accurately the effects of exposure to high sound levels on the auditory capacity of humans so far, the relationship between environmental noise and their non-auditory repercussions in the population is more uncertain.

Attending to physiological effects, exposure to intense noise levels over a period of time, generates hearing losses. In general, they are recoverable when noise ceases, however prolonged exposure can become irreversible over time. Likewise, exposure to medium-intensity noise levels with greater extension over time impacts similarly, both situations cause temporary or permanent displacements of the hearing threshold (World Health

Organization, 2018). Thus, in vehicle traffic it is recommended to limit exposure to their noise at 53 decibels, since above that level is associated with adverse health effects (World Health Organization, 2018). It should be noted, that the studies developed so far show various relationships between noise levels and hearing loss, hence, it is complex to measure this phenomenon.

The acoustic signal that perceives the brain has an impact on the whole organism, producing various effects difficult to determine and evaluate. It is known that noise lead to negative effects of physiological type that affect the respiratory system, blood pressure and muscle tension (World Health Organization, 2018). In addition, the negative effects of noise are prolonged at the psychological level by affecting the performance of the person in the execution of daily activities. Noise affects the concentration capacity and performance at work, producing fatigue, irritation, stress and social relationship problems.

1.3. Normative and Acoustic Legislation

The European Union with the aim of regulating noise emissions produced by human activity, has proposed a series of standards through specific legislation. This legislation established by the European Commission has evolved noticeably over the years. In 1992, the Action Program related to the environment and sustainable development was approved, whose objective was to prevent the population from being exposed to noise levels greater than 65 dB(A) and in no case exceed 85 dB(A) throughout the day (Halperin, 2014). Later, in the year 1996 the European Commission becomes aware of the importance of homogenizing the noise environment normative through the Green Paper (EU Commission, 1996). Finally, in 2002, the Directive 2002/49/EC is adopted in order to set the assessment methods of noise exposure.

1.3.1. National Legislation

On November 18, 2003, Law 37/2003 is published which is complemented by the Royal Decrees 1513/2005, 1367/2007 and 1038/2012 that propose a number of measures to prevent, monitor, reduce and if necessary to correct acoustic contamination in the national territory with the aim of avoiding and reducing the damages associated with human health, goods or environment (Ley 37/2003). This law proposes as a main measure the implementation of noise maps in order to obtain information about acoustic contamination levels. It introduces the concept of acoustic servitude area, which seeks a balance between transport infrastructures with the uses and activities of the areas affected by noise. In addition, the confection of strategic noise maps (SNM) is required in those places where agglomerations of more than 250 000 inhabitants occur, to evaluate the exposure of the population to certain levels of acoustic contamination, and update them every 5 years. This law establishes three different schedules in which the maximum allowed noise levels will be different in each of them. Day, evening and night period. The scheduled values that set out of the beginning and end of the different periods are:

- Day period (L_d): 7.00-19.00 (12h).
- Evening period (L_e): 19.00-23.00 (4h).
- Night period (L_n): 23.00-7.00 (8h).

Consequently, Royal Decree 1513/2005, of December 16 go further and not only covers the acoustic contamination produced by environmental noise, but also the one that is caused by vibrations and its implications in health, material goods and environment, as long as this type of pollution derives from environmental noise and its immediate effect on the population. Likewise, the subsequent Royal Decree 1367/2007, of October 19, contributes to noise control through acoustic zoning, quality objectives and acoustic emissions. In addition, the acoustic quality objectives applicable to the different acoustic areas including their buildings are established, fixing the values of the acoustic indexes that should not be exceeded for compliance (Table 1).

Table 1. Acoustic quality objectives for noise applicable to urbanized areas according to Royal Decree 1367/2007.

Acoustic area type		Noise Indexes		
		L_d (dBA)	L_e (dBA)	L_n (dBA)
e	Sectors of the territory with a predominance of soil for sanitary, teaching and cultural use that requires a special protection against noise pollution.	60	60	50
a	Sectors of territory with residential floor dominance.	65	65	55
d	Sectors of the territory with tertiary use floor predominance other than the one contemplated in c.	70	70	65
c	Soil Sectors with Soil Predominance recreational and show use.	73	73	63
b	Soil Sectors with Soil Predominance of industrial use.	75	75	65
f	Sectors of the territory affected by general transport infrastructures systems, or other public equipment that claim them. (1)	--(2)	--(2)	--(2)

(1) In these sectors of the territory, adequate measures for the prevention of acoustic pollution will be adopted, in particular through the application of the technologies of lower acoustic incidence among the best available techniques, in accordance with section a), of article 18.2 of Law 37/2003, of November 17.

(2) In the perimeter limit of these territory sectors will not exceed the acoustic quality objectives for noise applicable to the rest of adjacent acoustic areas with them.

1.3.2. Autonomic Legislation

On December 3, the Community of Valencian implemented Law 7/2002 of protection against acoustic contamination, where the acoustic quality objectives according to the dominant use of the soil are defined (Table 2). This Law is modified by Law 14/2005 published on December 23, 2005, which includes two decrees: Decree 266/2004 on December 3 establishing prevention and correction rules against acoustic contamination in relation to activities, facilities, buildings, works and services, as well as the Decree 104/2006 on July 14 of the Consell, about planning and management on acoustic contamination, whose purpose is to complement the regulative plans and acoustic programs written in Title III of the Decree 266/2004.

Table 2. Quality objective levels according to Law 7/2002.

	Sound Level dB(A)	
Dominant use of the soil	**Day (from 8h to 22h)**	**Night (from 22h to 8h)**
Sanitary and Education	45	35
Single-family residence	50	40
Residential	55	45
Tertiary	65	55
Industrial	70	60

In order to identify the problems and establish preventive and corrective measures necessary to maintain sound levels below those envisaged in this law, the Autonomous Community of Valencia establishes Saturated Acoustic Zones (SAZ) such as those areas where high sound levels occur due to the existence of numerous recreational activities, shows or public establishments, the activity of the people who use them, the traffic noise of these areas as well as any other activity that encourages the saturation of the sound level of the zone. Thus, SAZ will be declared to those that exceed twice a week for three consecutive weeks or, three alternates within a period of 35 calendar days, and in more than 20 dB (A), even though each individually considered activity complies with the levels established in this law (Ordenanza Municipal del Ayuntamiento de Valencia, 2008). However, only the City Council has the obligation to declare and carry out the zoning of a SAZ.

Once declared a SAZ area, the following measures will be taken for the reduction of acoustic contamination:

a) Suspend the granting of activity licenses.
b) Establish restricted schedules for the development of activities, be directly or indirectly responsible for the high levels of acoustic contamination.
c) Prohibit the circulation of some kind of vehicles or restrict their speed, or limit the speed at certain schedule in accordance with the other administrations.

1.3.3. Local legislation

In relation to the management of acoustic contamination in the local scope, the Valencia City Council approves the municipal ordinance against noise and vibrations by plenary agreement in 28/1996. This ordinance has been improved with the development of a new municipal noise ordinance approved as an agreement dated on May 30, 2008.

In this document, the management of road traffic is written by ordering the circulation in the urban roads, passing from two senses of circulation to a single sense, with which their circulatory intensities decrease, as well as the sound levels reached. In addition, the creation of new road infrastructures with lower steps and round belts is raised, moving away the traffic noise from the residential urban nucleus. Finally, the emission of heavy vehicle circulation licenses will be controlled (Ordenanza Municipal del Ayuntamiento de Valencia, 2008).

1.4. Municipal context of the study zone

The city of Valencia is located northeast of Spain, is the capital of a homonymous province, as well as the Valencian Community. It is a population of Mediterranean culture, with a population of 801,545 inhabitants, is the center of a metropolitan area that surpasses one and a half million (Requena et al., 2021). This city represents 15.9% of the population of Valencian Community and is, by demographic size, the third city of Spain after Madrid and Barcelona (Requena et al., 2021).

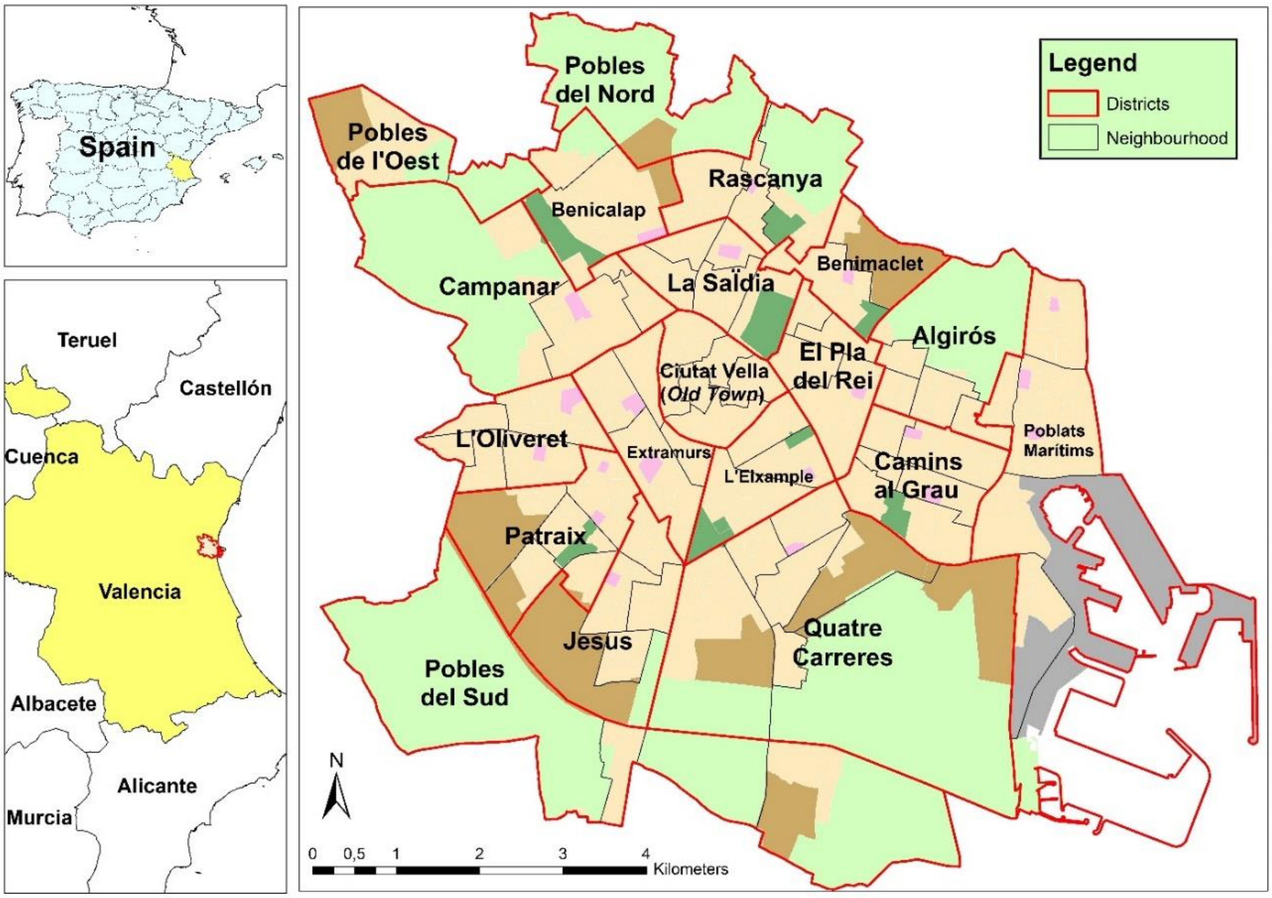


Figure 2. Administrative division of Valencia city.

This city is divided administratively in 19 districts, which in turn, are composed by 88 neighborhoods (Figure 2). Due to the high population density of the historical center, also called Ciutat Vella district, the Department of Sustainable Mobility undertook a series of measures to protect the patrimonial environment and improve the quality of life in the district, following the action proposal 1.2.1 of the plan for Sustainable Urban Mobility of Valencia City (2016). These measures would meet the following objectives:

- Reorganize the parking space, so that the most sustainable displacements are prioritized, ensuring the correct accessibility of resident persons and economic activities.
- Guarantee and order access for supply vehicles, complying with the need for commercial distribution and vehicles that transport people with reduced mobility.
- Decrease the traffic intensity in this especially sensitive residential area, preserving it to a large extent from the emission of noise, gases, smoke and polluting particles.
- Achieve a reduction of pollution, both acoustically and environmental, reduction of energy consumption and costs associated with it. Reduction, in short, greenhouse gases and increased quality of life.

These actions redirect the intense traffic of the Ciutat Vella district towards its exteriors, affecting the neighborhoods that surround it. With this reform, Ruzafa could be the most affected neighborhood as it is located southeast to the historical center. To be more accurate, Ruzafa is the one that has presented more complains due to acoustic contamination (Ajuntament de València, 2019). Moreover, a proposal has even been submitted to declare it as a SAZ which has been recently rejected by the Mayor of Valencia.

1.5. Objectives

This study will serve as the first contribution to the management and control of the current environmental acoustic contamination that is generated in one of the most densely populated neighborhoods in Valencia, affecting around 23826 inhabitants. By digitizing the terrain and all its urbanistic will be obtained the noise maps (NMs) through an acoustic prediction model for which CadnaA software will be used. NMs will indicate the distribution of noise pollution of the study zone, which will be validated with on-site measurements made by noise stations of Valencia City Council. These NMs will be useful to create a strategic noise map (SNM) through complementing the information with a geostatistical analysis of the area and the number of inhabitants who live the study zone.

Keeping in mind the analyzed problematic, the central objective of this study will be to evaluate and characterize the noise existing in the Ruzafa neighborhood according to a one-year record of traffic data and sound levels data. The purpose of this study is that it serves as a tool to improve Ruzafa acoustic quality through the following specific objectives:

- To perform an acoustic map by modeling the entire urban area.
- To evaluate the surface and the number of inhabitants exposed to the acoustic contamination caused by road traffic.
- To evaluate if the acoustic limits established by the current national and autonomic legislation are being fulfilled.

CHAPTER 2. MATERIALS AND METHODS

2.1. Study zone

Around 23826 people inhabit Ruzafa which has a total area of 87,8 ha, resulting in a population density of around 271,4 pd/ha, compared to 160,2 pd/ha of the historical center. According to the last report presented by the Statistics Office of City Council (2020) this neighborhood records the most vehicular amount of the entire city reaching up to 12375 units. All this background information could serve as indicators to demonstrate the large number of people who could be affected by the acoustic contamination that is happening in Ruzafa neighborhood.

By taking a tour of the main streets of Ruzafa neighborhood, a series of sensitive areas were selected (zones to be protected) in which traffic noise can be likely to disrupt the population critically, such as school centers and health centers. In addition, the areas of high, medium and low traffic flow were checked. The streets with great vehicular influx correspond to the large roads located towards the north and the south of the study area. The medium vehicular intensity corresponds to the avenues located east and west of Ruzafa. Finally, the low traffic flow is represented by the internal streets of the neighborhood.

On the other hand, the location of each City Council's noise station was checked, as well as, the positions of each of the traffic lights were scored, identifying areas with a large number of them. According to De Coensel et al. (2007) the abundance of traffic lights along the road crosses influences the sound levels emitted by vehicles due to the acceleration and deceleration they produce while waiting red traffic light. For all this, the study area was divided into three parts (Figure 3) depending on three factors: the abundance of both vehicle flux and traffic lights as well as the number of noise stations by verifying its equitable distribution.

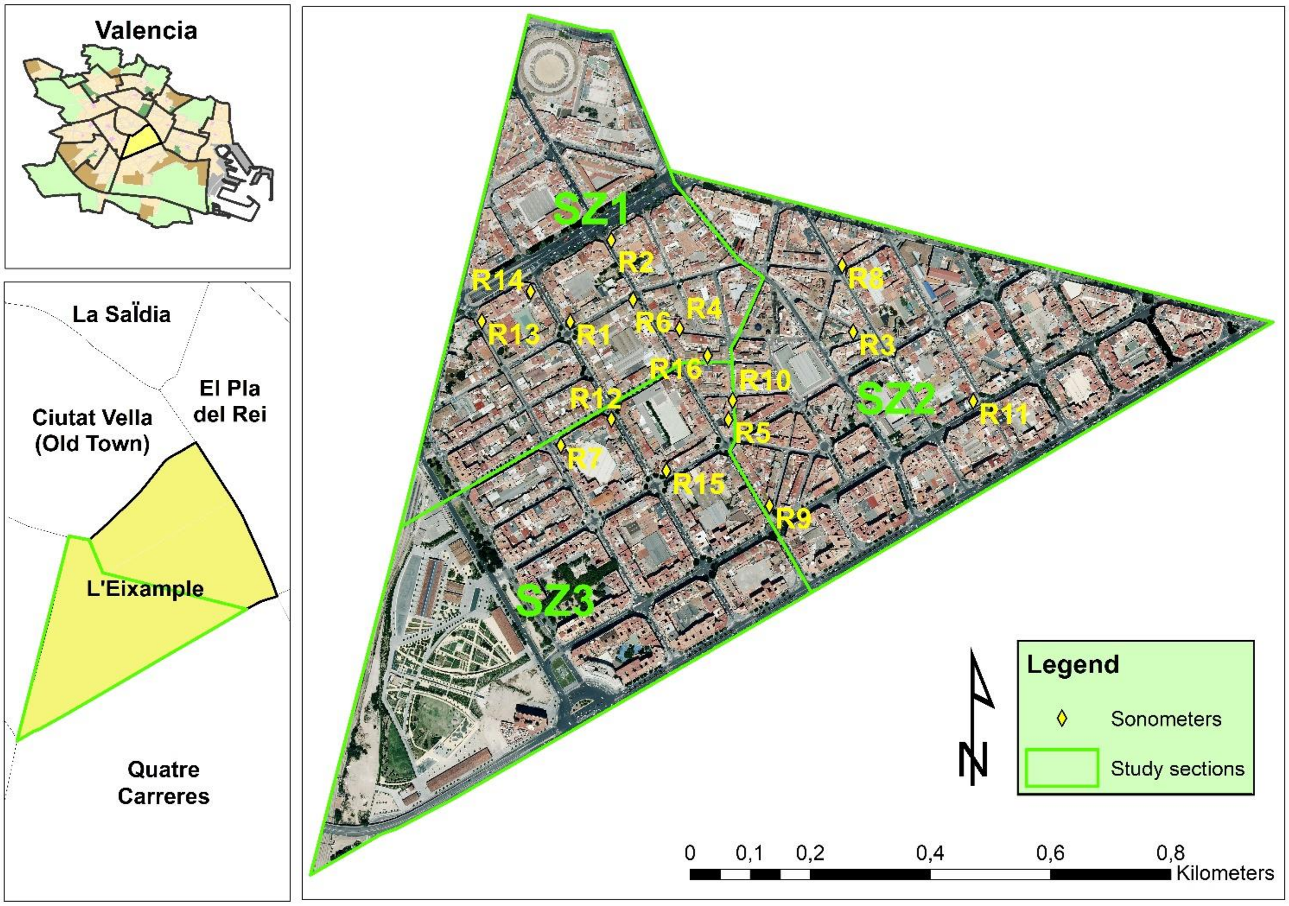


Figure 3. Segmentation of the study zone.

The study zone has a set of areas where commercial and leisure activity is concentrated which connect with the main communication routes. However, the vast majority of the surface is established for residential use. The streets located outside the main roads, have as a main feature their narrowness, typical of the historical center. The majority of urban vehicle traffic surfaces are asphalted. In the case of the sidewalks located next to built-up areas are composed of concrete cobblestones. In the same way, roads of non-pedestrian use are built as an asphalt. Regarding the road arrangement, this neighborhood is composed of the following main roads depending on the study divisions:

- The section 1 (SZ1) is located north of the study area and it is not regulated for too many traffic lights. Germanies major road is the one that the most vehicular traffic shows in the entire study zone, this road crosses this section. In addition, it is surrounded by the streets: Ruzafa and Maestro Aguilar to the east, Gibraltar and Alicante streets to the west, and finally Játiva street located to the North (Figure 4).
- The section 2 (SZ2) is located southeast and it is composed by the avenues Peris y Valero and Reino de Valencia as main roads which surround the section.

Moreover, four secondary streets can be found; Cádiz to the west, Ciscar to the east, and finally Maestro Aguilar together with Matias Perelló that crosses the section. It should be noted that this area contains a lot of traffic lights that regulate the crossing roads (Figure 4).

- Finally, section 3 is located southwest and it is delimited by Peres y Valero that become Giorgeta avenue. Moreover, four secondary roads cross this section; Cádiz, Sueca, Filipinas and Centelles streets (Figure 4).

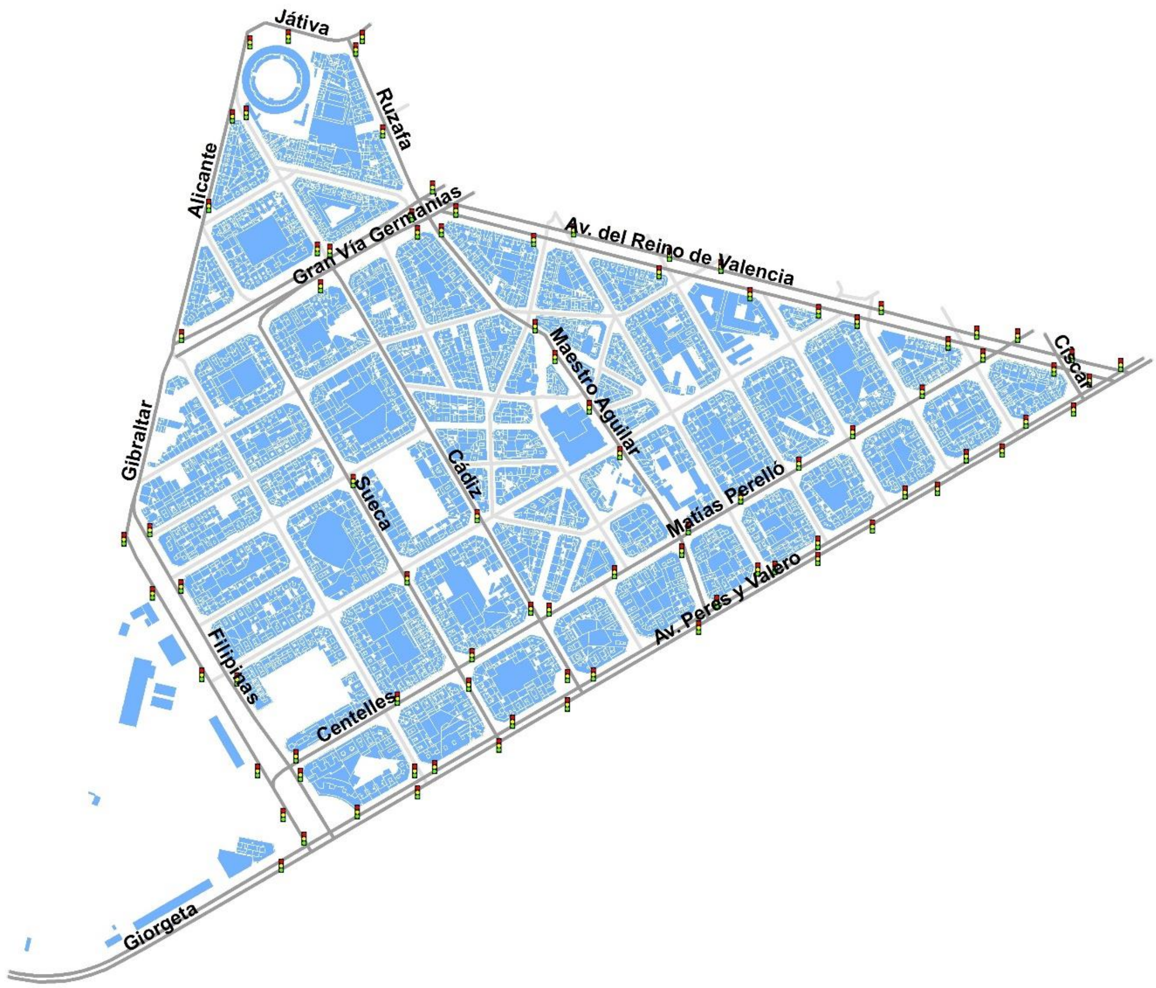


Figure 4. Cartographic configuration of the study zone

2.2. Materials

Following the guidelines of Directive 2002/49/EC, strategic noise maps (SNM) is a technical document that must reflect at least two different parts:

- Sound level maps that represent isophone lines made from the calculation of acoustic levels through the use of noise indexes: L_n and L_{den}.
- Tables or maps of noise exposure that include surface and population exposed to certain noise levels, and other data required by Law 37/2003 where noise law in Spain is developed.

2.2.1 Noise indexes used in acoustic contamination

Noise is a physical magnitude that presents considerable variations on both noise type and its magnitude. These noise variations are represented as a function of time exposure, therefore maximum exposure limits have been set. Because of this, a series of indexes representing this form of energy are established:

- **Equivalent continuous sound level (L_{eq})**

Acoustic measurements record many different instantaneous values during a given time and it is necessary to express the result of the measurement by a simple number that represents the overall magnitude of measurement. The equivalent continuous sound level without weight is used as an average value that encompasses all variations of the sound level during the entire measured period (see equation 1).

$$L_{eq,T} = 10 \cdot log\left(\frac{1}{T}\int_0^T \frac{P^2(t)}{P_0^2}dt\right) \tag{1}$$

Where:

T is the total measurement period.

$P(t)$ is the sound pressure for the moment t.

P_0 is the reference pressure (in the air, 20 μPa).

In order to know how the human ear would listen certain noise, the A-weighted sound level ($L_{Aeq,T}$) measurements is applied. This scale penalizes low and high frequency noise and increases the level of medium frequencies. In addition, it is an acoustic parameter used internationally as an indicator of the degree of acoustic discomfort. For this reason, it is the most used in studies of acoustic pollution in order to assess the degree of impact generated in people, it is expressed in dB(A) and is calculated by the following expression (see equation 2):

$$L_{Aeq,T} = 10 \cdot log\left(\frac{1}{T}\sum_i 10^{\frac{L_i}{10}} \cdot t_i\right) \tag{2}$$

Where:

T is the total measurement period.

t_i is the duration of i-period.

L_i is the sound pressure level in the i-period.

Moreover, European Commission (Directive 2002/49/CE) and National (Real Decreto 1513/2005) which is developed by the State Law (Ley 37/2003), select the day-evening-night noise level (L_{den}), and the night noise level (L_n) for the elaboration of the strategic noise maps (SNM). However, Spanish legislation goes beyond and through Noise Law (Real Decreto 1367/2007), establishes the noise levels of the day (L_d), afternoon (L_e) and night (L_n) to evaluate the acoustic quality objectives of the different types of acoustic areas, in order to evaluating compliance with the limit values set for acoustic emitters. These indicators of sound levels are suitable for assessing medium to long-term environmental noise, generated in residential areas, cities and agglomerations.

- **Day noise level (L_d)**

It is an indicator of the sound level during a day, defined as the long-term sound level determined throughout all one-year-old day periods. It corresponds to 12 hours a day, in the period that extends from 7am until 7pm.

- **Evening noise level (L_e)**

It is an indicator of the sound level during the evening, defined as the long-term sound level determined throughout all the day periods of one year. It corresponds to 4 hours, in the period that extends from 7pm until 11pm.

- **Night noise level (L_n)**

It is an indicator of the sound level during the night, defined as the long-term sound level determined throughout all the night periods of one year. It corresponds to 8 hours a day, in the period that extends from 11pm until 7am.

- **Day-evening-night noise level (L_{den})**

It is an indicator of the global noise level during the day, afternoon and night, used to determine the hassle linked to exposure to noise. This index gives an idea of the noise level over 24 hours a day. However, it has a 5 dB(A) penalty for the equivalent sound levels corresponding to the evening period and 10 dB(A) for those of the night. This penalty is applied to consider the greatest discomfort that noise produces in the evening and night. Although sound levels usually decrease to some extent during these periods, its relative importance increases. To calculate it (see equation 3), the equivalent sound levels for the day (L_d), evening (L_e) and night (L_n) are added as follows:

$$L_{den} = 10 \cdot log\left[\frac{1}{24}\left(12 \cdot 10^{\frac{L_d}{10}} + 4 \cdot 10^{\frac{L_e+5}{10}} + 8 \cdot 10^{\frac{L_n+10}{10}}\right)\right] \quad (3)$$

Where:

L_d is the day noise level.

L_e is the evening noise level.

L_n is the night noise level.

- **Day-night noise level (L_{dn})**

This indicator gives an idea of the noise level over 24 hours a day, taking into consideration the fact that during the night the population becomes more sensitive to noise. It is common that sound levels decrease to some extent during the night period, however, its relative importance increases. This indicator has a penalty of 10 dB for equivalent levels measured during the night and is calculated (see equation 4) using the equivalent day indicator L_d and the equivalent night indicator L_n as follows:

$$L_{dn} = 10 \cdot log\left[\frac{1}{24}\left(16 \cdot 10^{\frac{L_d}{10}} + 8 \cdot 10^{\frac{L_n+10}{10}}\right)\right] \quad (4)$$

Where:

L_d is the day noise level.

L_n is the night noise level.

The application of homogeneous parameters and criteria that allow comparing the noise data obtained in different territorial areas is fundamental in the evaluation and management of environmental noise. Therefore, as it is established by the current acoustic legislation, all these indexes will be used to evaluate exposure to noise caused by road traffic.

2.2.2. Data frame acquisition

First, several field trips were performed through the entire study area. In these visits, the position of both, sonometers and traffic lights network was mapped. In addition, the road configuration was recorded with the aim of knowing the most relevant characteristics of them: width, length and pedestrian streets. Moreover, open databases that come from the different government entities exposed in table 3, were necessary to carry out the digitization of the study area.

Table 3. Database for acoustic modeling

Data	Format	Year	Scale	Description	Responsible agency
Cartographic and topographic data					
Administrative limits	Vector	2014	1:5000	Municipal, district and neighborhood limits	ICV
Land uses	Vector	2018	1:5000	Land uses layer	ICV
DEM	Raster	2021	1:50000	Digital elevation model	ICV
Buildings	Vector	n.d	1:5000	Building layer	Ministerio de Hacienda y Función Pública
Population	Vector	n.d	1:5000	Number of people who live in each building	Ajuntament de València
Road traffic parameters					
ADT	Table	2020/2021	n.d	Average daily traffic	Ajuntament de València
Road network	Vector	2014	1:5000	Municipal road network	ICV
Pedestrian streets	Table	2014	1:5000	Sidewalks and pedestrian streets	ICV
Road direction	Vector	2014	1:5000	Number of traffic lanes and direction senses	ICV

[1]ICV: Institut Cartogràfic Valencià.

Secondly, all relevant information about the average daily traffic of vehicles (ADT) traveling through the main streets was requested to the City Council of Valencia, as well as the data of the sound levels with on-site measurements made by noise stations located in the Ruzafa neighborhood. Some of these sonometers have been updated through the Technical Pollution section of Valencia City Council. The sonometers have the most recent technology, which includes the transmission of direct data with a Brue & Kjaer data processing, which has already been tested with excellent results. These are Class 1 Sonometers of B&K Type 2250-L.

2.2.3. Time series data format and quality control

Furthermore, the ADT comes from the daily records of 21 roads, while the sound levels (L_d, L_e, L_n and L_{den}) come from 16 on-site sonometer, as well as daily records. Both parameters have one year of records, from September 2020 until August 2021. To rearrange these raw data into ready tractable time series the statistical software R (R Foundation, n.d.) was used by making a code. The purpose of this conversion was to better visualize the data, the subsequent processing of time series and a first quality control.

First, the time series data were imported. At this point, the time series data: ADT and sound levels data were analyzed taking into account the entire time period (September 2020 - August 2021). The further geostatistical analysis will rely on good quality data. One important criterion is that time series are not affected by error measurements, change in sonometers position or punctual noise measurements. The time series selected in this study were quality controlled before the analysis. This quality control involves visual inspection through histograms and basic statistics (Table 4 and 5).

Table 4. Average daily traffic of vehicles with their standard error.

Road code	Description	ADT
A105	FILIPINAS, between Gibraltar & Peris y Valero	$(16{,}563 \pm 0{,}010)10^3$
A118	GERMANIAS, between Ruzafa & Túnel	$(54{,}717 \pm 0{,}018)10^3$
A120	MARQUES DEL TURIA, between Hernán Cortés & Ruzafa	$(59{,}284 \pm 0{,}019)10^3$
A155	MATIAS PERELLO, from Av. Antiguo Reino & Maestro Aguilar	$(9{,}715 \pm 0{,}030)10^3$
A16	ALICANTE, from Játiva to Germanías	$(2{,}659 \pm 0{,}007)10^3$
A163	MESTRE RACIONAL, from Jacinto Benavente to Av. Antiguo Reino	$(8{,}524 \pm 0{,}018)10^3$
A187	PERIS Y VALERO, between Ausias March & Zapadores	$(34{,}089 \pm 0{,}040)10^3$
A188	PERIS Y VALERO, between Av. Amado Granell Mesado & Alcalde Reig	$(36{,}451 \pm 0{,}025)10^3$
A189	P.E. AV. GIORGETA, between San Vicente & Ausias March	$(51{,}149 \pm 0{,}019)10^3$
A190	PERIS & VALERO, between Zapadores & Av. Amado Granell Mesado	$(38{,}676 \pm 0{,}037)10^3$
A20	ANTIGUO REINO, between Germanías & Matías Perelló	$(13{,}788 \pm 0{,}009)10^3$
A21	ANTIGUO REINO, from Matías Perelló to Peris & Valero	$(10{,}944 \pm 0{,}014)10^3$
A217	RUZAFA, from Germanías to Colón	$(7{,}604 \pm 0{,}006)10^3$
A218	RUZAFA + MAESTRO AGUILAR Peris & Valero to Germanías	$(5{,}166 \pm 0{,}009)10^3$
A264	GIBRALTAR, from Buenos Aires to G.V. Germanías	$(6{,}572 \pm 0{,}007)10^3$
A386	SUECA, from Literato Azorín to Puerto Rico	$(2{,}404 \pm 0{,}006)10^3$
A55	CADIZ, from Germanías to Peris & Valero	$(3{,}960 \pm 0{,}006)10^3$
A68	CENTELLES, between Maestro Aguilar & Filipinas	$(9{,}935 \pm 0{,}030)10^3$
A73	CISCAR, from Antiguo Reino to Marqués del Túria	$(4{,}887 \pm 0{,}009)10^3$
A77	COLON, from Sorní a Ruzafa	$(10{,}864 \pm 0{,}010)10^3$
B59	JÁTIVA, between Ruzafa & Alicante	$(20{,}038 \pm 0{,}011)10^3$

Table 5. Sound levels with their standard error.

Code	Monitoring station	Experimental $L_{Aeq,d}$ [dB]	Experimental $L_{Aeq,e}$ [dB]	Experimental $L_{Aeq,n}$ [dB]	Experimental $L_{Aeq,den}$ [dB]
R1	**T248652**	(60,8 ± 0,4)	(60,2 ± 0,6)	(53,0 ± 0,7)	(62,6 ± 0,2)
R2	**T248655**	(66,7 ± 0,3)	(64,2 ± 0,3)	(58,5 ± 0,4)	(68,0 ± 0,3)
R3	**T248661**	(57,4 ± 0,5)	(54,0 ± 0,6)	(47,7 ± 0,6)	(58,1 ± 0,5)
R4	**T248669**	(62,2 ± 0,2)	(60,7 ± 0,4)	(54,2 ± 0,6)	(63,7 ± 0,4)
R5	**T248670**	(61,7 ± 0,4)	(60,8 ± 0,6)	(53,4 ± 0,8)	(63,3 ± 0,6)
R6	**T248671**	(62,9 ± 0,3)	(60,9 ± 0,5)	(54,3 ± 0,6)	(64,2 ± 0,4)
R7	**T248672**	(59,3 ± 0,4)	(58,7 ± 0,6)	(53,5 ± 0,6)	(62,0 ± 0,5)
R8	**T248676**	(60,8 ± 0,4)	(58,4 ± 0,4)	(52,2 ± 0,5)	(61,9 ± 0,4)
R9	**T248677**	(63,0 ± 0,3)	(62,7 ± 0,5)	(54,6 ± 0,6)	(64,6 ± 0,4)
R10	**T248678**	(58,7 ± 0,5)	(57,4 ± 0,7)	(50,6 ± 0,9)	(60,5 ± 0,6)
R11	**T248679**	(62,7 ± 0,3)	(61,7 ± 0,4)	(55,0 ± 0,4)	(64,3 ± 0,3)
R12	**T248680**	(62,2 ± 0,4)	(62,2 ± 0,7)	(54,5 ± 0,8)	(64,4 ± 0,6)
R13	**T248682**	(61,5 ± 0,3)	(59,1 ± 0,4)	(52,6 ± 0,5)	(62,6 ± 0,4)
R14	**T248683**	(63,0 ± 0,2)	(62,0 ± 0,2)	(55,4 ± 0,3)	(64,5 ± 0,2)
R15	**T248684**	(62,2 ± 0,3)	(62,7 ± 0,6)	(54,2 ± 0,8)	(64,3 ± 0,5)
R16	**T251234**	(59,7 ± 0,4)	(58,2 ± 0,9)	(50,1 ± 1,0)	(61,3 ± 0,7)

One other important criterion is that the time series do not show magnitude changes with time, namely they are stationary. Stationary series are much easier to analyze. If they behaved in a certain way in the past (with a certain mean and variance), we can assume that they will continue to behave in the same way in the future. In addition, as can be observed in tables 4 and 5, the value of the standard error of the average is sufficiently low for both, ADT and sound levels, which indicates a more accurate estimate of the average sample. Under this stationary assumption all the statistical analysis and inference out the time series are assumed to be valid.

2.3. Methods

2.3.1. Digitization process

The use of GIS as a geographic information system allowed the manipulation of the diversity of information sources, as well as the administration of large amounts of geographic and alphanumeric data involved in the model. Among other tasks, the geometry of spatial data was processed for buildings, roads, traffic lights network and vegetable areas with the ArcGIS as input parameters (Figure 5).

During the execution of the SNM, the GIS were used for tasks such as:

- Population calculations per square meter of residential surface.
- Simplification of the buildings and calculation of the height of them.
- Identification and assignment of the land uses to the buildings.
- Obtaining the facades most exposed based on the values calculated by the CadnaA receivers.
- Exposed population calculations using a 4x4 mesh, as required by autonomous regulations (Ley 7/2002).
- Assembly of maps that include assignment of colors, legends, labels, among others.

An acoustic simulation software will facilitate the calculation of noise levels for specific sources, in this case road traffic. To perform the three-dimensional model for the subsequent mathematical calculations of the traffic noise propagation, has been used the CadnaA acoustic simulation software, in the version 4.3 (DataKustik GmbH). This model will be the information base for the execution of the NM, because it constitutes a complete software package for calculation and presentation of exposure levels to environmental noise. This predictive software is specially optimized to solve the requirements raised by Directive 2002/49 EC.

CadnaA communicates optimally with other applications such as text processors, spreadsheets, professional drawing programs (AutoCAD), geographic information systems (GIS) and databases (Figure 5). This feature allows to import/export both graphic data and databases that facilitates the compatibility of integrating all the starting information in a single computer environment, perform the preparation of the maps and once the results are obtained, export the data in compatible formats with geographic information systems.

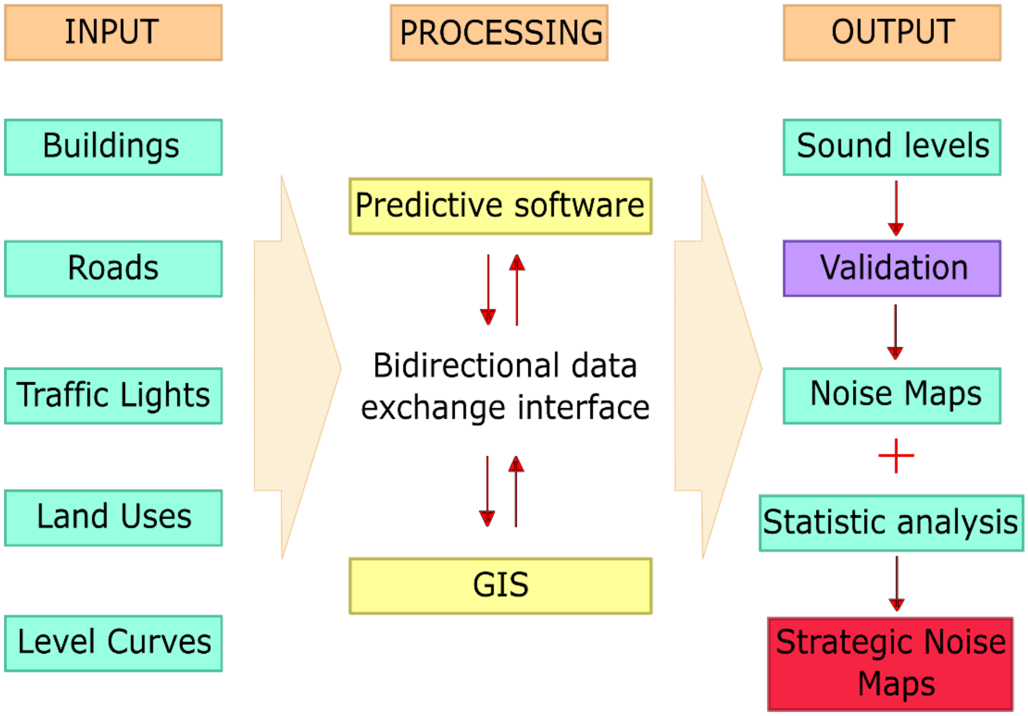


Figure 5. Methodology of the acoustic modeling carried out in this study

For simulation, the program requires information about the sources of road traffic, features of the environment in which the propagation of sound is studied, and the location of the different receivers. Therefore, in the creation of the digital model, the cartographic of the area were taken as departure data. The cartography contains information related to the topography of the terrain, arrangement of the buildings and identification of the use of the land.

2.3.2. Configuration of the roads structure

For the modeling of the roads, the municipal road network provided by the ICV (Institut Cartogràfic Valencià, 2014) was used as a basis, which were digitized according to the height of the terrain and the level curves each meter, considering the number of streets and their width, therefore, the accuracy obtained is this study is comparable with the real platform of the road. In addition, the information on the roads was complemented by the reassignment of slopes calculated from a digital elevation model. However, this attribute did not suppose a decisive feature for the calculation of sound levels since the study area does not exceed 15 meters above sea level.

The acoustic simulation model assigns a linear source for each direction and section of the road, therefore, the roads that exceeded the two lanes and have both directions of circulation (road code: A20, A21, A105, A118, A120, A187, A188, A189 and A190) were separated and digitized as two different streets dividing the ADT in two equal parts as recommend CadnaA user manual for a greater precision in the modeling (Datakustic, 2005).

In terms of the composition of the roads, no available information was found. However, according to the guidelines carried out for the preparation of the last SNM of Valencia in 2017, the roads can be considered as smooth asphalt (Ajuntament de Valencia, 2007).

Regarding the vehicular flow rates, it was introduced the data measured in the corresponding traffic stations of the different road sections. For the speeds, the allowed limits were considered, being 50 km/h for the main roads and 30 km/h for the secondaries. Likewise, it was checked that the traffic of the roads that surround the study zone (A20, A105, A118, A120, A187, A188, A189 y A190) have a pulsed traffic type due to the acceleration and deceleration of vehicles, while the interior roads show a fluid continuous traffic (the rest of the roads).

2.3.3. Configuration of the buildings structure

The data of the buildings belonging to the study zone were obtained with a 1: 5000 scale, provided by the Ministry of Finance and Public Function through the electronic cadastre headquarters. These data were verified by the most current orthophotos of the Spanish Geographic Information Center (IGN).

The level of detail of each building influence the final quality of an acoustic study. Thus, for large areas of study, European regulations recommends the simplification of buildings in order to save resources in the development of the project (Directive 2002/49 / EC). However, the City Council of Valencia recommends that the studies inferior to district should be addressed with the highest level of detail as possible, with the object to achieve a representation as close as possible to reality (Ajuntament de Valencia, 2007).

Because of this, the buildings were maintained with the highest level of detail, assigning the heights through the ArcGIS software, previous in situ verification of the number of plants. Starting from a minimum height of 4 meters, increasing in 3 meters per additional plant.

By the other hand, a study of the sensitive buildings (sanitary/educational and tertiary) of the study area has been carried out in order to identify those buildings susceptible to being affected by road traffic. These buildings are:

- CEIP Alejandra Soler
- CEIP Jaime Balmes
- CIPFP Vicente Blazco Ibáñez

- Colegio San José
- Escuelas Profesionales de Artesanos
- Centro de Salud Ruzafa
- Mercado de Ruzafa
- Parroquia San Bartolomé
- Parroquia de San Valero
- Parroquia San Francisco Borja

To calculate the levels of immission on the facades of buildings with acoustic sensitivity, point receptors distributed on the outside of each of the facades were defined at 4 meters high with respect to the floor and separated from each other with a minimum length of 3 meters and maximum of 10 meters, as long as the facade allows it.

For the perceived level in each of these receivers, the incident level on the evaluated facade was estimated considering the reflections in the adjacent buildings and obstacles. The facades of the buildings are characterized as totally reflective (sound absorption coefficient Alpha Sabine = 0), since there was no information about the composition of the facade material.

2.3.4. Setting up calculation and mesh

To characterize the traffic noise sources, it was used the French method NMPB-Routes-96, as indicated in the Noise Law 37/2003 and the Royal Decree 1513/2005. The propagation distance of the noise is 1000 meters and it was used reflections of order 2. In addition, a 4x4 receptor mesh was used with a height of 4 meters above the ground, following local regulations (Ajuntament de Valencia, 2007).

On the other hand, since the study area does not have special meteorological features, the conditions indicated in the ISO 1996-1: 2020 standard are applied in relation to environmental noise management (Asociación Española de Normalización, 2020). The meteorological conditions will be defined as follows: the day will have 50% favorable conditions, the evening will have 75% favorable, and 100% favorable conditions for the night. Temperature will be around 15ºC and relative humidity 75%.

2.3.5. Geoprocessing model to evaluate the exposure to noise

The geostatistical theory will allow predictions on the study zone providing information about the affected surface and the exposed population to different intervals of noise levels. These results are obtained by creating a geoprocessing model using the ArcGIS software.

This model has the ability to evaluate all the parameters introduced into the scheme of figure 6.

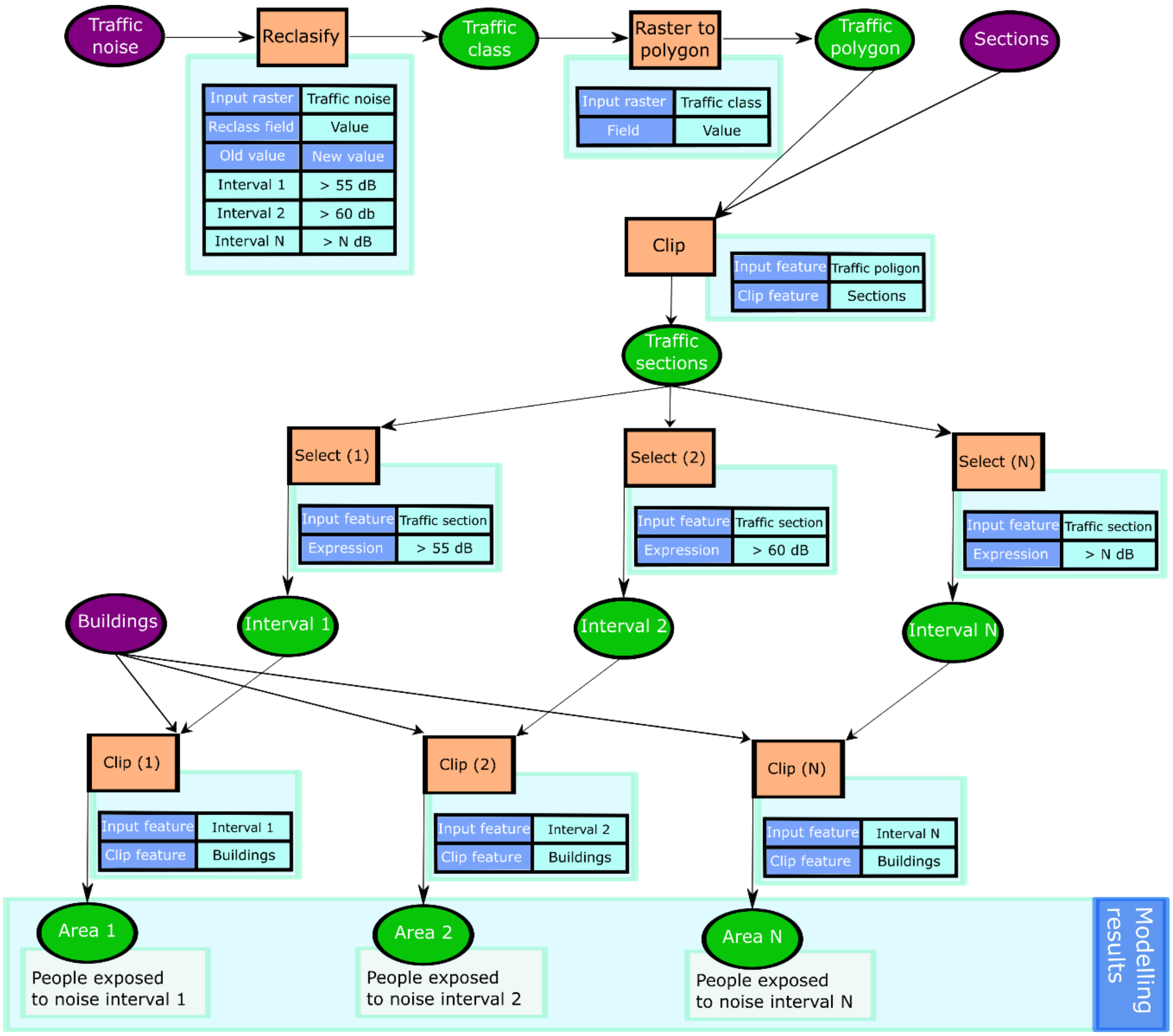


Figure 6. Model to find areas and people exposed to noise levels by road traffic.

Once the acoustic maps modeled in the predictive software were obtained, the files were exported to be reclassified with GIS. This process of reclassification consists of a series of steps to finally identify the surface and number of people affected by the different levels of sound emissions.

First, the areas representing the sound levels are selected by intervals (from 35 dB to 80db), with the aim of identifying the affected surfaces. Second, using the population density per square meter of each building it is possible to quantify the number of people affected. Finally, the percentages of the people are calculated to make a correspondence with the actual number of inhabitants that are found in the study area following the Spanish Regulations regarding to the representation of the data (Real Decreto 1513/2005).

CHAPTER 3. RESULTS AND DISCUSSION

3.1. Validation of the acoustic model

In order to demonstrate the validity of the noise maps, the experimental values measured through the sound stations will be compared with the values obtained by simulation in the points that were introduced as receivers in the predictive software.

For the validation of the model generated in the acoustic simulation program CadnaA, punctual receivers were positioned 4 meters from the ground, using the UTM coordinates of the on-site sound stations.

The calculation was performed for the periods of 24 hours, day, evening and night in each receiver with the sources of road noise activated. Immission levels perceived by punctual receivers were imported and compared with experimental values (Table 6), subsequently, correlate them and evaluate the quality of the simulation.

Table 6. Comparative of experimental sound levels against simulates for the 24 hours period and the night period.

		$L_{Aeq,den}$ [dB]			$L_{Aeq,n}$ [dB]		
Code	**Monitoring station**	**Experimental**	**Simulated**	**Deviation**	**Experimental**	**Simulated**	**Deviation**
R1	**T248652**	62,6	62,8	-0,2	53,0	52,1	0,9
R2	**T248655**	68,0	69,8	-1,8	58,5	59,4	-0,9
R3	**T248661**	58,1	57,2	0,9	47,7	46,9	0,8
R4	**T248669**	63,7	62,0	1,7	54,2	52,6	1,6
R5	**T248670**	63,3	63,4	-0,1	53,4	54,0	-0,6
R6	**T248671**	64,2	63,2	1,0	54,3	53,6	0,7
R7	**T248672**	62,0	60,7	1,3	53,5	51,1	2,4
R8	**T248676**	61,9	62,4	-0,5	52,2	51,6	0,6
R9	**T248677**	64,6	66,7	-2,1	54,6	57,2	-2,6
R10	**T248678**	60,5	59,6	0,9	50,6	50,0	0,6
R11	**T248679**	64,3	65,7	-1,4	55,0	55,7	-0,7
R12	**T248680**	64,4	65,5	-1,1	54,5	54,8	-0,3
R13	**T248682**	62,6	64,1	-1,5	52,6	53,2	-0,6
R14	**T248683**	64,5	66,6	-2,1	55,4	55,9	-0,5
R15	**T248684**	64,3	62,9	1,4	54,2	52,4	1,8
R16	**T251234**	61,3	61,8	-0,5	50,1	52,0	-1,9

Taking into account the absolute values, the standard deviation of the difference between experimental values and simulated, is 1,5 dB for period of 24 hours and 1,5 dB for the night period. Since 100% of the simulated values deviate less than 3 dB of the experimental values, there was no condition or data to be changed on the simulation model. This same condition is fulfilled for both the day and evening period (Table A1).

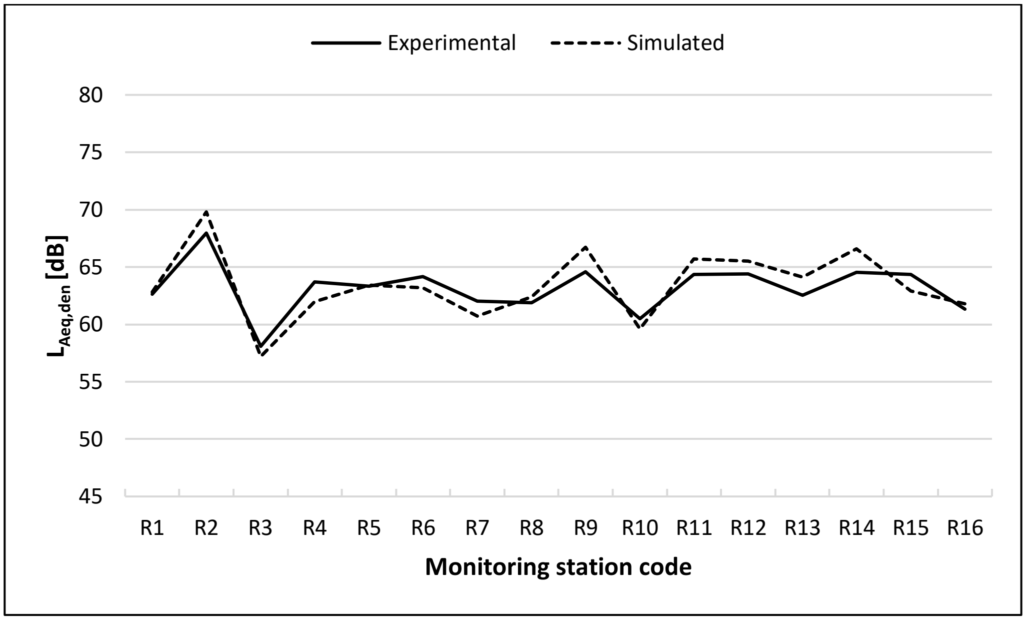


Figure 7. Comparative behavior between experimental values and simulates for the 24 hours period.

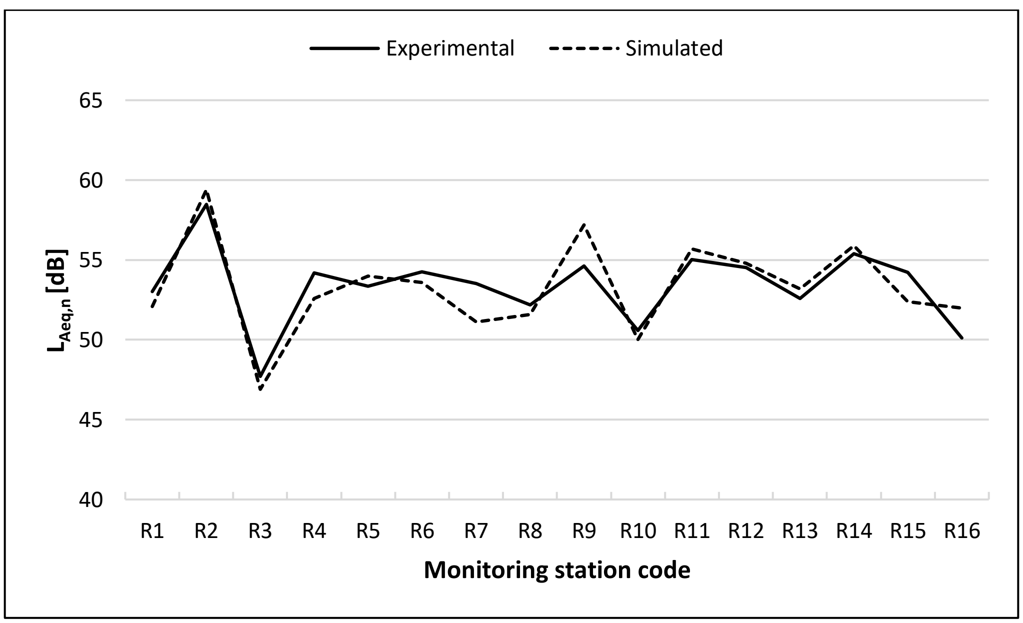


Figure 8. Comparative behavior between experimental values and simulates for the night period.

In the figure 7 and 8, the comparison between the measured and simulated values can be observed. The simulated measures do not have a great variation with respect to the experimentals measurements. However, simulated measures tend to overestimate sound levels. This is due to the level of detail of the obstacles, in this case the buildings, and also beacuse it was established an order 2 for the reflections. The same results for the period of day and evening, can be observed in the annexes (Figure A1 and A2).

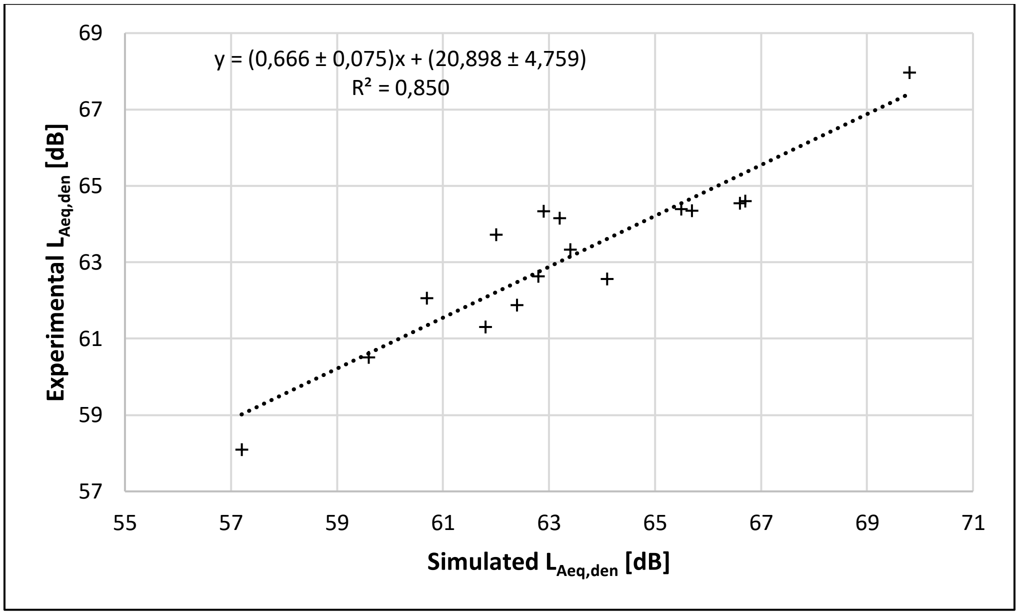


Figure 9. Validation of the noise map through linear correlation for the 24 hours period.

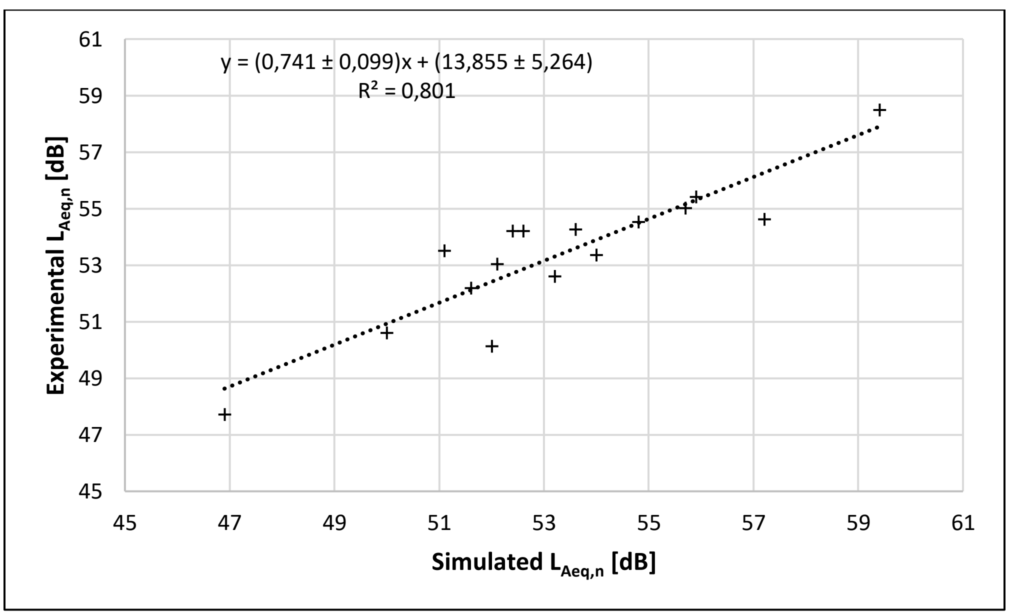


Figure 10. Validation of the noise map through linear correlation for the night period.

Finally, to validate the creation of the noise maps, the level of dependence between the experimental vs simulated values can be observed in the figures 9 and 10. There is a very high linear correlation, R2 = 0,85 for the 24 hours period and R2 = 0,80 for the night period, between experimental and simulated values, a similar correlation can be found in the annexes for the day and evening period (Figure A3 and A4). This last indicator validates the simulation and therefore the noise level maps will represent a good approximation to the real situation of the Ruzafa neighborhood as far as noise generated by road traffic is concerned. Once the simulation method is validated, the noise map levels are obtained at 4 meters according to the ISO 1996-1 standard and the results are displayed in the following section.

3.2. Ruzafa noise maps

According to Directive 2002/49/CE of the European Parliament and of the Council of 25 June 2002 on Evaluation and Management of Environmental Noise says *"Member States shall apply the indicators of noise L_{den} and L_n in the preparation and revision of the strategic noise maps"*. However, in Law 37/2003 about noise treatment, the L_d and L_e evaluators are included to carry out the preparation of this type of maps in Spain. For this reason, in the strategic noise maps, the isophone curves are represented from 35 dB to 80 dB for each period of the day (L_d, L_e, L_n and L_{den}). Subsequently, it can be seen the areas with acoustic sensitivity, such as residential, sanitary, educative and tertiary areas.

The surface land exposed in Ruzafa neighborhood to the different sound levels caused by acoustic pollution of road traffic will allow to obtain information about: what is the percentage of the surface susceptible to levels above the limits and what Ruzafa zones are susceptible to being identified as quiet areas due to the low noise level to which it is subjected.

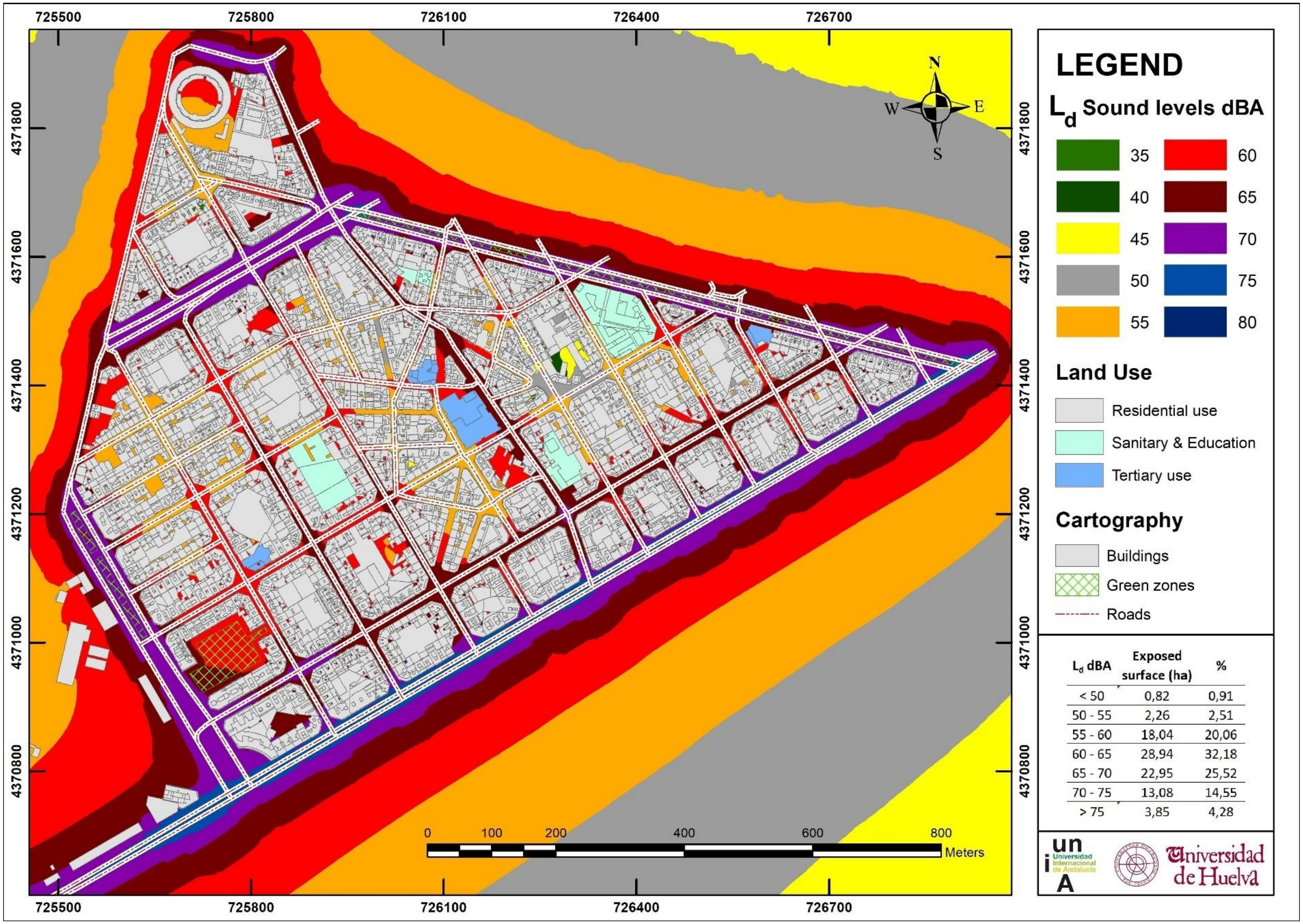
All these results will be presented by considering the legislative framework in terms of maximum levels allowed by the National Law (65 dB for L_d and L_e and 55 dB for L_n) and by the Autonomic Law (55 dB for the day and 45 dB for the night) for sensitivity areas with residential predominance.

In the period 24 hours, 56.75% of the surface shows levels greater than 65 dB, exceeding national regulations. Based on this, noisy and calm areas seem to be equally distributed. On the contrary, if we take in consideration the acoustic levels established by the autonomic regulations, only in the 2% of the area of Ruzafa neighborhood are generating sound levels below 55 dB. In other words, almost all of the area of Ruzafa, about 87 hectares, exceed this limit transforming the whole neighborhood into a noisy area (Figure 14).

Throughout the day, on the largest area of the Ruzafa neighborhood, around 56%, sound levels are generated below the acoustic limit (< 65 dB) established by national regulations. Which means that the noisy areas and calm areas have fifty percent of dominance each one in the day period (Figure 11). On the contrary, only in 3.42% of the Ruzafa surface are generating acoustic levels within the autonomic regulations, which established the 55 dB limit for residential territory, leaving an impressive 96.58% surface that exceeds this limit (Figure 11).

In general terms, the evening period improves, since at 67.3% of the surface are produced sound levels smaller than 65 dB. However, the remaining percentage is still represented about 35 hectares where sound levels exceed national regulations (Figure 12). By counterpart, only 6.8% of the surface complies with the autonomous regulations which limits 55 dB for period. This leaves around 83 hectares (93%) out of this limit, resulting in noisy areas harmful for the inhabitants of Ruzafa neighborhood (Figure 12).

According to national regulations, during the night period, noisy areas and quiet areas are very balanced with 51.7% and 48.3% respectively since the limit in this period is 55 dB (Figure 13). However, acoustic pollution by road traffic in Ruzafa neighborhood is very aggravated considering the autonomous regulations that limit the emissions in 45 dB. Only 2.2% of the area of the neighborhood produces sound levels below this limit, leaving an excessive 97.8% that violate this regulation (Figure 13).



L_d dBA	Exposed surface (ha)	%
< 50	0,82	0,91
50 - 55	2,26	2,51
55 - 60	18,04	20,06
60 - 65	28,94	32,18
65 - 70	22,95	25,52
70 - 75	13,08	14,55
> 75	3,85	4,28

Figure 11. Noise map of the day period for Ruzafa neighborhood.

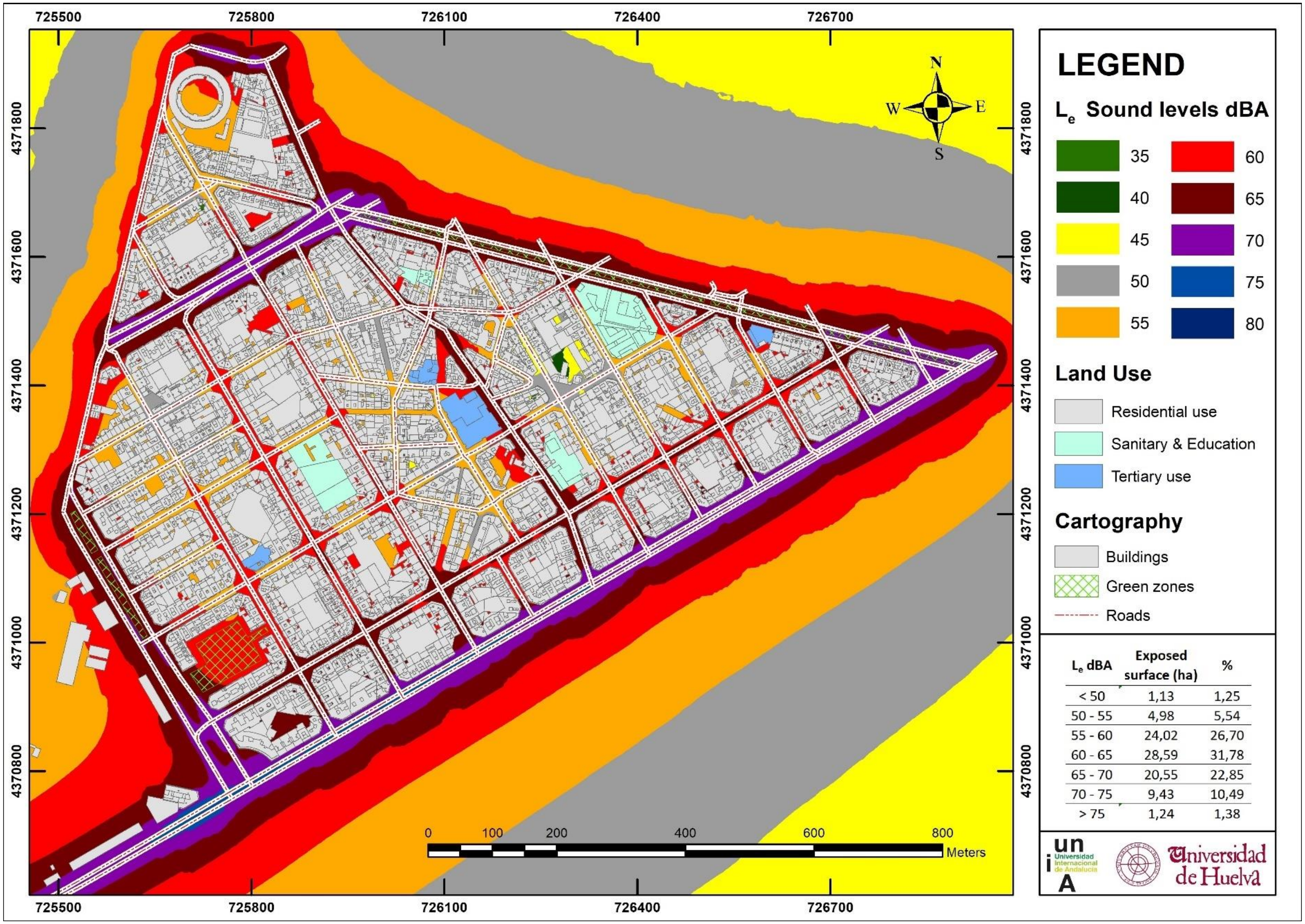


Figure 12. Noise map of the evening period for Ruzafa neighborhood.

L_n dBA	Exposed surface (ha)	%
< 45	1,93	2,15
45 - 50	12,94	14,39
50 - 55	28,53	31,73
55 - 60	26,25	29,18
60 - 65	15,10	16,78
65 - 70	5,19	5,77
> 70	0,00	0,00

Figure 13. Noise map of the night period for Ruzafa neighborhood.

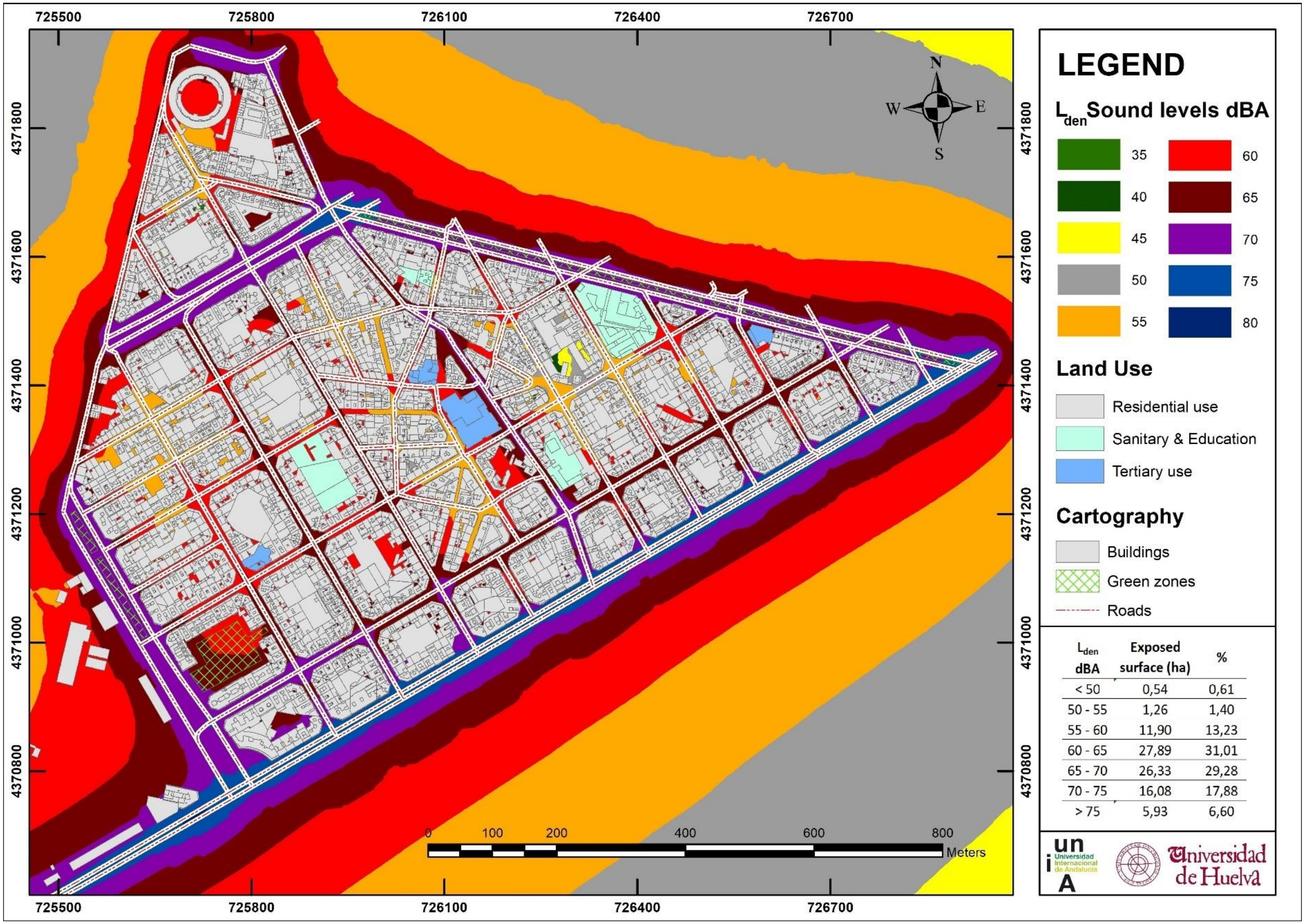


Figure 14. Noise map of the 24-hours period for Ruzafa neighborhood.

3.3. Diagnosis of noise exposure levels according to the policy framework

The NMs presented in the previous section allow differentiated information on the main noisy surfaces caused by road traffic. The differentiated analysis of these noisy surfaces by sectors will allow identifying, in each case, the noise level to which people are subjected independently.

For diagnosis by studied zones, the number of persons exposed to noise levels that do not comply with national legislation (> 65dB for the period 24 hours and > 55 dB for the night period) are presented below, as well as the percentage of people exposed at levels that meet this regulation. In addition, this same analysis will be carried out taking into account the autonomic legislation, which is stricter because it establishes the limit for the 24 hours period at 55 dB while for the night period is 45 dB.

The results of the number of exposed population were calculated for all periods of the day (L_d, L_e, L_n and L_{den}), however, as a summary, only those for the 24-hours period and those for the night period are presented below, the rest of the results can be seen on the annexes (Annexes B).

3.3.1 Study zone SZ1

Throughout 24 hours a day, the greatest number of people in SZ1, around 4282 (70.89%), are exposed to levels between 35 - 65 dB, complying with national regulations. While 29.11% of the population live in areas that do not comply with this law (Table 7). But if we talk about autonomous regulations, only 3.33% of the population live within the limit of decibels allowed (55 dB) for residential territory, leaving 5840 inhabitants (around 96.67%) outside the range of allowed levels.

By the other hand, 73.68 % of the population in this sector, live within the range of sound levels (≤ 55 dB) that comply with national regulations for the night period (Table 8). On the contrary, if we take into account that the autonomous regulations become stricter in this period, only 3.85% of people live in areas that comply with the regulations, which means that around 5807 people (96.15 %) are exposed to levels not allowed by the autonomous law (Table 8).

Table 7. Population exposed in SZ1 to noise produced by road traffic in the 24 hours range.

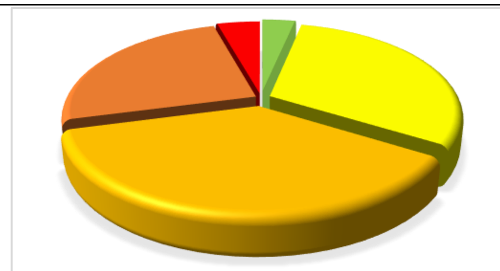
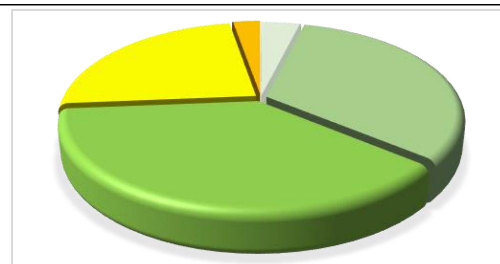
24 HOURS (L_{den})			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	201	3,33	
55 - 60	1.838	30,43	
60 - 65	2.243	37,13	
65 - 70	1.497	24,78	
70 - 75	262	4,33	
> 75	0	0,00	

Table 8. Population exposed in SZ1 to noise produced by road traffic in the night range.

NIGHT (L_n)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 45	232	3,85	
45 - 50	1945	32,20	
50 - 55	2273	37,63	
55 - 60	1.426	23,61	
60 - 65	163	2,71	
> 65	0	0,00	

3.3.2. Study zone SZ2

SZ2 shows an increase in people exposed to noise levels greater than 65 dB, in the 24-hour period compared with SZ1 (table 7 & 9). In particular, 5137 inhabitants (50.91%) live in areas that do not comply with national policies. Moreover, the percentage of people living in areas within the limits established by autonomous laws does not improve, since only 5.17% are exposed to sound levels less than 55 dB, leaving 94.83% that does not comply with autonomic regulations (Table 9).

If we only take into account the national law, half of the inhabitants of SZ2 live within the limit established for the night period (≤ 55 dB), leaving attentively 5017 of people exposed to higher levels than 55 dB (Table 10). On the contrary, 94.65% of the population in SZ2 live in areas that violate autonomic regulations, since these areas exceed the limit established for the night period (> 45 dB). Only 5,34 % of people live in areas that comply this law.

Table 9. Population exposed in SZ2 to noise produced by road traffic in the 24 hours range.

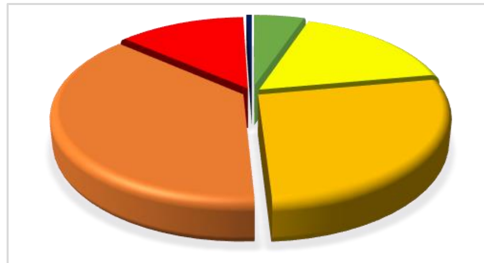
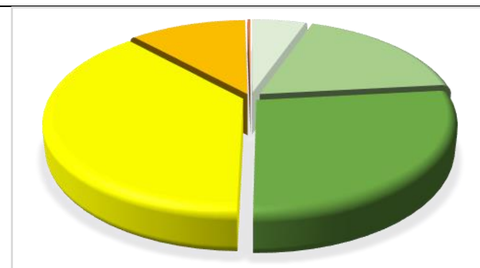
24 HOURS (L_{den})			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	522	5,17	
55 - 60	1709	16,93	
60 - 65	2724	26,99	
65 - 70	3770	37,36	
70 - 75	1313	13,01	
> 75	54	0,54	

Table 10. Population exposed in SZ2 to noise produced by road traffic in the night range.

NIGHT (L_n)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 45	539	5,34	
45 - 50	1811	17,94	
50 - 55	2727	27,02	
55 - 60	3826	37,90	
60 - 65	1163	11,52	
> 65	28	0,27	

3.3.3. Study zone SZ3

SZ3 is the sector with greater sound disorder along the 24-hours period, because there is a huge increase in the percentage of people exposed to levels greater than 65 dB with respect to SZ1 and SZ2 (Tables 7, 9 and 11). The 61.72% of people live in areas where acoustic levels violate with national regulations. What is even more extraordinary is that only 0.25% of inhabitants comply with autonomic regulations, leaving almost the entire population of this sector, around 6724 people, exposed to levels that violate autonomic law.

Talking about the night period, there is also an increase in the percentage of people who live exposed to sound levels greater than 55 dB. Specifically, 61.01% of the population of this sector live in areas that fail to comply with national regulations. But the scenario is even more critical if we take into account autonomic regulations, since 99.76% of the population lives in areas that exceed the acoustic levels allowed during the night (Table 12).

Table 11. Population exposed in SZ3 to noise produced by road traffic in the 24 hours range.

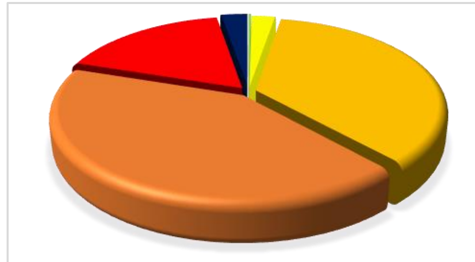
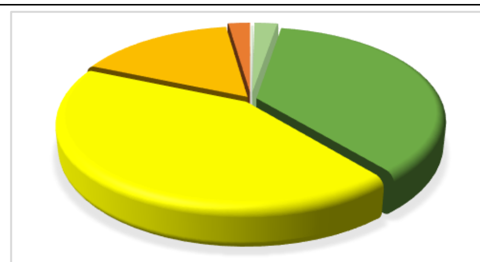
24 HOURS (L_{den})			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	17	0,25	
55 - 60	162	2,40	
60 - 65	2401	35,63	
65 - 70	2815	41,76	
70 - 75	1164	17,27	
> 75	182	2,69	

Table 12. Population exposed in SZ3 to noise produced by road traffic in the night range.

NIGHT (L_n)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 45	17	0,25	
45 - 50	161	2,40	
50 - 55	2450	36,35	
55 - 60	2862	42,46	
60 - 65	1096	16,27	
> 65	154	2,28	

3.4. Analysis of the acoustic sensitive areas

Tables 13 and 14 show the results of the facade analysis on each sensitive area, which allow characterizing the acoustic quality of the buildings sensitive to noise. The analysis was carried out by considering both national regulations and autonomic regulations, in order to know if buildings with acoustic sensitivity are exposed to allowed sound levels.

Table 13. Immission sound levels in buildings with acoustic sensitivity during day period.

Acoustic area	Name	L_d [dBA]	Compliance RD 1367/2007	Compliance Law 7/2002
Tertiary	Mercado de Ruzafa	59,9	YES	YES
Tertiary	Parroquia San Bartolomé	65,1	YES	YES
Tertiary	Parroquia de San Valero	60,2	YES	YES
Tertiary	Parroquia San Francisco Borja	58,8	YES	YES
Sanitary & Education	CEIP Alejandra Soler	57,2	YES	NO
Sanitary & Education	Centro de Salud Ruzafa	47,6	YES	NO
Sanitary & Education	CEIP Jaime Balmes	64,5	NO	NO

Sanitary & Education	CIPFP Vicente Blazco Ibáñez	65,4	NO	NO
Sanitary & Education	Escuelas Profesionales de Artesanos	65,4	NO	NO
Sanitary & Education	Colegio San José	57,4	YES	NO

Table 14. Immission sound levels in buildings with acoustic sensitivity during night period.

Acoustic area	Name	L_n [dBA]	Compliance RD 1367/2007	Compliance Law 7/2002
Tertiary	Mercado de Ruzafa	51,2	YES	YES
Tertiary	Parroquia San Bartolomé	55,5	YES	NO
Tertiary	Parroquia de San Valero	51,8	YES	YES
Tertiary	Parroquia San Francisco Borja	50,5	YES	YES
Sanitary & Education	CEIP Alejandra Soler	48,6	YES	NO
Sanitary & Education	Centro de Salud Ruzafa	39,6	YES	NO
Sanitary & Education	CEIP Jaime Balmes	55,7	NO	NO
Sanitary & Education	CIPFP Vicente Blazco Ibáñez	56,2	NO	NO
Sanitary & Education	Escuelas Profesionales de Artesanos	55,8	NO	NO
Sanitary & Education	Colegio San José	47,8	YES	NO

It is necessary to highlight from the analysis of tables 13 and 14 that the educational centers: *Ceip Jaime Balmes, CIPFP Vicente Blazco Ibáñez* and *Escuelas Profesionales de Artesanos*, are those most affected by the noise produced by road traffic since they are exposed to sound levels that do not comply with the national and autonomic regulations.

3.5. Estimation of the percentage of highly annoying people by traffic noise

On one side, the SNMs present noise levels that affect the population directly (objective analysis). However, they also present perception studies (subjective analysis) of the same noise, such as surveys to the population. Since in this work, no subjective studies were carried out, it has been chosen to estimate through a formula the number of people who consider the noises suffered as highly annoying (ISO 1996-1).

The following estimation are made based on relating noise levels produced by road traffic and the hassle response of the inhabitants of the studied areas (dose-effect relationship). A proposal has been submitted by the Dosage/Effect Working Group 2 (WG2) of the European Union (equation 5). This working group recommends that the percentages of highly annoying people (HA) must be used as a noise discomfort descriptor in the affected population and is calculated as follows:

$$HA = \frac{100}{(1 + e^{10,4-0,132L_{dn}})\%} \tag{5}$$

Table 15. Percentage of the population very annoyed by the road traffic noise.

Sector	Monitoring station code	HA (%)
SZ1	R1	9,47
	R2	18,12
	R4	11,06
	R6	11,63
	R13	9,71
	R14	12,35
	R16	12,35
SZ2	R3	5,69
	R8	9,04
	R9	11,87
	R11	11,91
SZ3	R5	10,20
	R7	8,94
	R10	7,19
	R12	11,19
	R15	11,00

The previous table can be observed the study carried out by the percentage of population that is affected by the noise generated in the Ruzafa neighborhood (Table 15). As a general rule around 10% of the population living in this neighborhood is very annoyed by traffic noise.

CHAPTER 4. CONCLUSION

By using time series such as base data for both, to calculate the acoustic levels produced by road traffic as well as to validate the immission levels into the receivers, they have proved to be the best option to carry out accurate acoustic evaluation. Although, the predicted acoustic levels tend to overestimate the experimental levels, the differences do not exceed 3 dB in any case (Table 6), indicating the accuracy that have the time series due to its sample size.

On the other hand, through the analysis of noise maps, it can be seen as a general pattern that all roads surrounding the study areas are the sources that greater acoustic pollution provide, especially the Avenue *Peres y Valero* (Figure 11, 12, 13 and 14). Because of this, the quiet areas are located in the core of each study section.

The quiet areas are considered those that comply with the limits established by the different regulations. According to the limits established in the Royal Decree 1367/2007, Ruzafa has equally distributed the noisy and quiet areas with a 50 % each one for both day period as well as the night period (Figure 11 and 13). However, during the evening period, quiet areas dominate over the noisy areas by 65% (Figure 12). On the contrary, noisy areas massively exceed (with around 90%) to quiet areas in all periods of the day (Figure 11, 12, 13 and 14), considering the acoustic limits established in the Autonomic Law 7/2002. Starting from this fact, the acoustic reality of the night period is especially problematic, since this period range is intended for the night's rest of the inhabitants of Ruzafa, therefore, special insistence should be made to give a solution.

Even though in the Ruzafa neighborhood, several action plans have been carried out, such as pedestrianization of interior streets and the increase of a bicycle lane, but in its vast majority, noise levels are still high, especially in the road ring that surround the neighborhood.

Because in SZ2 there is a greater number of people living per square meter with respect to SZ1 and SZ3, it could be thought that it is the most affected sector, due to its higher population density. However, SZ3 is the most affected area of the Ruzafa neighborhood since it connects three main road axes; *Filipinas* street, Av. *Giorgeta* and Av. *Peres y Valero*. Which produces an increase in the surface affected by acoustic levels between 60 and 70 dB for the night period (Figure 13) and between 70 and 80 dB for the rest of the periods (Figure 11, 12 and 14). From this the following is deduced:

> Regarding the population and using national regulations as a reference legislative framework, SZ1 has the lower acoustic incidences according to the exposed population, since around 70% of people are within the limit established for all

periods of the day (Tables 7 and 8), followed by SZ2 with around 50% and last SZ3 with 40% of people exposed to allowed acoustic levels (Tables 9, 10, 11 and 12).

However, the situation worsens drastically if we take as a reference the autonomic political framework. In summary, taking into account all the indexes that evaluate each period of day, both in SZ1 and SZ2 only around 5% of the population is exposed to levels allowed by the regulations (Tables 7, 8, 9 and 10). But what is even more incredible is that in SZ3 a very small percentage of people (around 0,3 %) complies with the regulations leaving the entire population exposed to levels higher than the target limit (Tables 11 and 12).

In addition, from the analysis of the L_{dn} index levels, the percentages of very annoying population could be estimated (Table 15). With these values, it is concluded that the population of SZ1 is the one that more discomfort perceives by the noise that produce the road traffic. While for SZ2 and SZ3, the very annoying population suppose the 10% each one. However, it is speculated that the percentage of annoying people in SZ3 is underestimated because the monitoring stations are not equally distributed in this area.

The analysis of acoustically sensitive areas shows a discordance in terms of compliance with national regulations compared to autonomic regulations. In the day period as well as the night period, the most areas with acoustic sensitivity comply with what is established by the Royal Decree1367/2007 (Table 13 and 14). However, all this panorama changes when we talk about the autonomic legislation that is established by the Autonomic Community of Valencia, because the opposite happens. The vast majority of areas with acoustic sensitivity do not comply with the limit established in Law 7/2002 (Table 13 and 14).

Finally, national and autonomic laws have the same hierarchical ranking. This means that both laws are governed by the principle of competition, not by the hierarchy principle, because of this, it is concluded that Ruzafa neighborhood not only does not comply with the established objective in terms of acoustic contamination, but it is well below this.

BIBLIOGRAPHY

Ajuntament de València. (2007). Criterios para la elaboración del mapa de ruido y planes de acción: Ciudad de Valencia (Diapositivas). https://sicaweb.cedex.es/docs/jornadas/2011-11-03/E_Brull.pdf

Ajuntament de València. (2017). *Planes de acción en materia de contaminación acústica del término municipal de Valencia*. https://sicaweb.cedex.es/docs/planes/Fase1/Aglomeraciones/ES_a_DF7_Agg_Valencia.pdf

Ajuntament de València. (2019). *Informe de Actuaciones*. https://www.valencia.es/documents/20142/281801/A_C4SUG_20200203_1330_0_firmadoweb.pdf/246e87cb-835a-f77e-c48f-63b41633a4ec?t=1613822811578

Ajuntament de València. (2020). Área de prioridad residencial de Ciutat Vella (APR Ciutat Vella Norte). https://www.valencia.es/es/-/area-de-prioridad-residencial-de-ciutat-vella

Ajuntament de València. (2021). *Información de los barrios de Valencia*. Portal de l'Ajuntament de la ciutat de València. Retrieved from https://www.valencia.es/es/cas/estadistica/mapa-barrios

Ajuntament de València. (n.d). *Criterios de elaboración del mapa de ruido y planes de acción*. https://sicaweb.cedex.es/docs/jornadas/2011-11-03/E_Brull.pdf

Asociación Española de Normalización. (2020). Acústica. Descripción, medición y evaluación del ruido ambiental (ISO 1996-1:2020).

Datakustic. (2005). CadnaA – Manual de Usuario versión 3.6 (Álava Ingenieros). Germany

De Coensel, B., Botteldooren, D., Vanhove, F., & Logghe, S. *Microsimulation based corrections on the road traffic noise emission near intersections*. Acta acustica united with acustica, 2007. 93(2), 241-252. Retrieved from https://www.ingentaconnect.com/content/dav/aaua/2007/00000093/00000002/art00007

Decreto 266/2004, de 3 de diciembre, del Consell de la Generalitat, por el que se establecen normas de prevención y corrección de la contaminación acústica en relación con actividades, instalaciones, edificaciones, obras y servicios. Diario oficial de la Generalidad Valenciana, 4901. España 2004.

Decreto 104/2006, de 14 de julio, del Consell, de planificación y gestión en materia de contaminación acústica. Diario oficial de la Generalidad Valenciana, 5305. España 2006.

Directive 2002/49/CE of the European Parliament and of the Council of 25 June 2002 on Evaluation and Management of Environmental Noise. Official Journal of the European Communities, 2002.

EU Commission. (1996). The green paper on future noise policy. COM (96), 540.

Halperin, D. *Environmental noise and sleep disturbances: A threat to health?* Sleep Science, 2014. 7(4), 209-212. https://doi.org/10.1016/j.slsci.2014.11.003

Instituto Geográfico Nacional. (2021). Centro nacional de información geográfica. Geoportal oficial del Instituto Geográfico Nacional de España. Retrieved from http://centrodedescargas.cnig.es/CentroDescargas/index.jsp

Kinsler, L. E., Frey, A. R., Coppens, A. B., & Sanders, J., V. (2000). *Fundamentals of Acoustics* (4th ed.). Wiley.

Kumbhar, S., Maji, S., & Kumar, B. (2014). Automotive vibration and noise control using smart materials: a state of art and challenges. *World Journal of Engineering*. https://doi.org/10.1260/1708-5284.10.6.535

Ley 7/2002, de 3 de diciembre, de protección contra la contaminación acústica. Diario oficial de la Generalidad Valenciana. Valencia, 2002.

Ley 37/2003, de 17 de noviembre, del Ruido. Boletín Oficial del Estado, 276. España, 2003.

Ley 14/2005, de 23 de diciembre, de la Generalitat, de Medidas Fiscales, de Gestión Financiera y Administrativa, y de Organización de la Generalitat. Diario oficial de la Generalidad Valenciana, 5166. España 2005.

Martyr, A. J., & Rogers, D. R. *Vibration and noise*. Engine Testing, 2021. 217–234. https://doi.org/10.1016/B978-0-12-821226-4.00008-5

Morales, J. (2009). Estudio de la influencia de determinadas variables en el ruido urbano producido por el tráfico de vehículos. Tesis (Doctoral), E.T.S.I. Caminos, Canales y Puertos (UPM).

Möser, M., & Barros, J. L. (2009). Ingeniería Acústica. Springer Publishing.

Münzel, T., Sørensen, M., Schmidt, F., Schmidt, E., Steven, S., Kröller-Schön, S., & Daiber, A. *The Adverse Effects of Environmental Noise Exposure on Oxidative Stress and Cardiovascular Risk*. Antioxidants & Redox Signaling, 2018. 28(9), 873–908. https://doi.org/10.1089/ars.2017.7118

Ordenanza municipal de protección contra la contaminación acústica y vibraciones. (2008). Boletín Oficial de la Provincia de Valencia, 111. Valencia 2008. Retrieved from https://www.fvmp.es/pdf/ordenances-medi-ambient/contaminacio-acustica/ordenanca-ajuntament-valencia-contaminacio-acustica.pdf

R Foundation. (n.d.). The R Project for Statistical Computing. Retrieved from https://www.r-project.org/

Ramos, J. C., García, J. S. R., Caldas, C. Á., & Quesada, A. *Influencia de los Parámetros de Conducción en el Ruido Emitido por un Automóvil en el Tráfico Urbano*. XIX Congreso Nacional de Ingeniería Mecánica. 2012.

Real Decreto 1513/2005, por el que se desarrolla la Ley 37/2003, del Ruido, en lo referente a la evaluación y gestión del ruido ambiental. Boletín Oficial del Estado, 301. España, 2005.

Real Decreto 1367/2007, por el que se desarrolla la Ley 37/2003, del Ruido, en lo referente a zonificación acústica, objetivos de calidad y emisiones acústicas. Boletín Oficial del Estado, 254. España, 2007.

Real Decreto 1038/2012, por el que se modifica el Real Decreto 1367/2007, del Ruido, en lo referente a zonificación acústica, objetivos de calidad y emisiones acústicas. Boletín Oficial del Estado, 178. España, 2012.

Recio, A., Linares, C., Banegas, J. R., & Díaz, J. *Road traffic noise effects on cardiovascular, respiratory, and metabolic health: An integrative model of biological mechanisms*. Environmental Research, 2016. *146*, 359–370. https://doi.org/10.1016/j.envres.2015.12.036

Requena, L., Morales, T., Badenes, J., Martínez, F., Moya, C., Rodriguez, M., Requena, R., & Alba, S. (2021). *Dades, Estadístiques de la ciutat de València (N.º 3*). https://www.valencia.es/estadistica/pdf/Dades213.pdf

World Health Organization. (2018). *Environmental Noise Guidelines for the European Region.* World Health Organization.

ANNEXES

A. Validation of the acoustic model

Table A1. Comparative of experimental sound levels against simulates for the day period and the evening period.

		$L_{Aeq,d}$ [dB]			$L_{Aeq,e}$ [dB]		
Code	**Monitoring station**	**Experimental**	**Simulated**	**Deviation**	**Experimental**	**Simulated**	**Deviation**
R1	**T248652**	60,8	61,6	-0,8	60,21	59,9	0,3
R2	**T248655**	66,7	68,4	-1,7	64,2	66,7	-2,5
R3	**T248661**	57,4	55,9	1,5	54,0	54,1	-0,1
R4	**T248669**	62,2	60,2	2,0	60,7	58,5	2,2
R5	**T248670**	61,7	61,6	0,1	60,8	59,9	0,9
R6	**T248671**	62,9	61,5	1,4	60,9	59,8	1,1
R7	**T248672**	59,3	58,9	0,4	58,7	57,2	1,5
R8	**T248676**	60,8	61,2	-0,4	58,4	59,4	-1,0
R9	**T248677**	63,0	65	-2,0	62,7	63,2	-0,5
R10	**T248678**	58,7	57,8	0,9	57,4	56,1	1,3
R11	**T248679**	62,7	64,2	-1,5	61,7	62,5	-0,8
R12	**T248680**	62,2	64,3	-2,1	62,2	62,6	-0,4
R13	**T248682**	61,5	63	-1,5	59,1	61,2	-2,1
R14	**T248683**	63,0	65,4	-2,4	62,0	63,7	-1,7
R15	**T248684**	62,2	61,7	0,5	62,7	60	2,7
R16	**T251234**	59,7	60,1	-0,4	58,2	58,5	-0,3

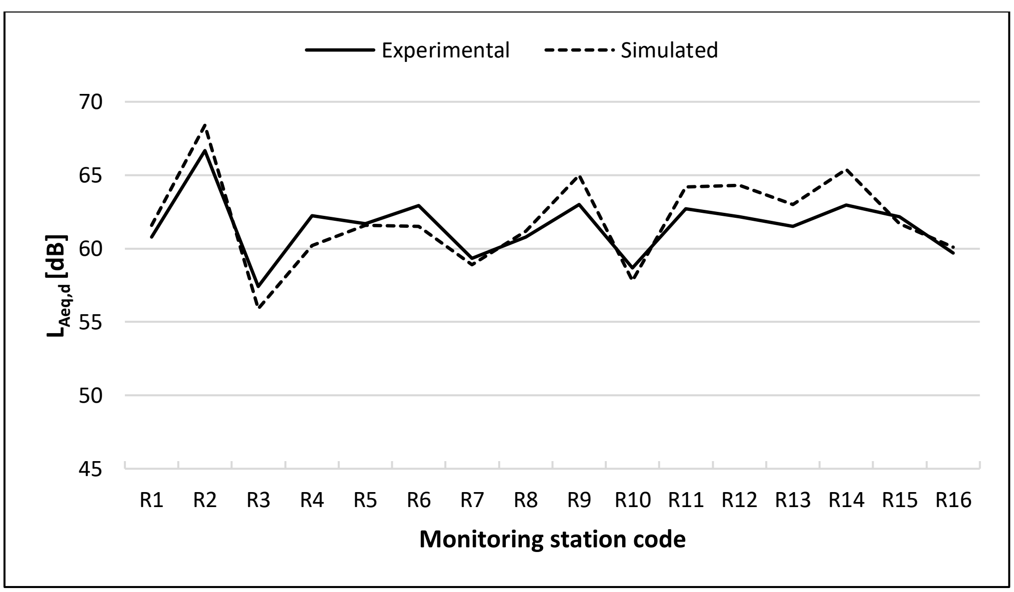


Figure A1. Comparative behavior between experimental values and simulates for the day period.

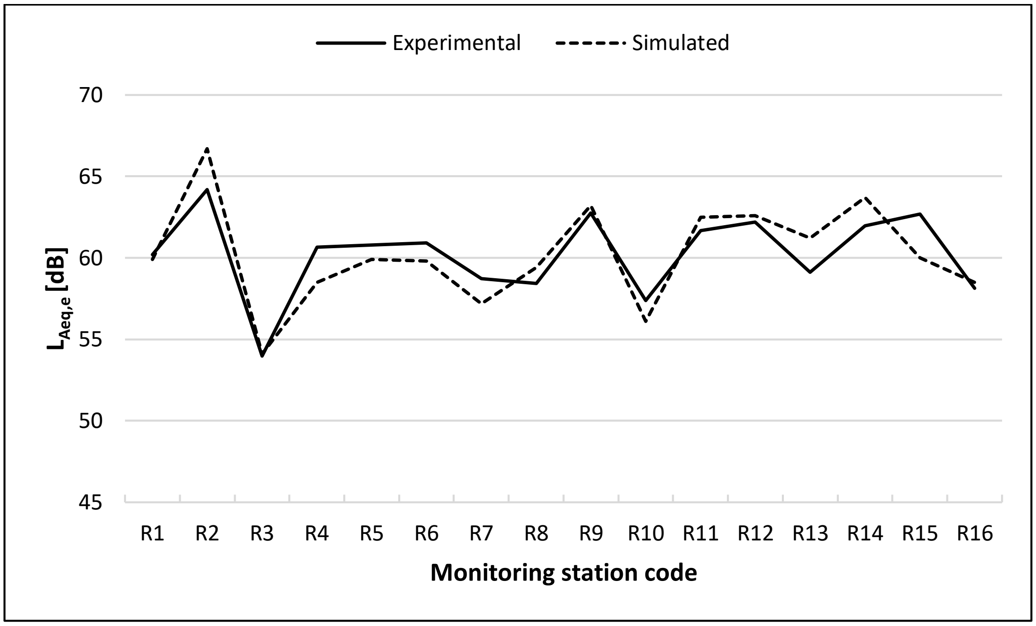


Figure A2. Comparative behavior between experimental values and simulates for the evening period.

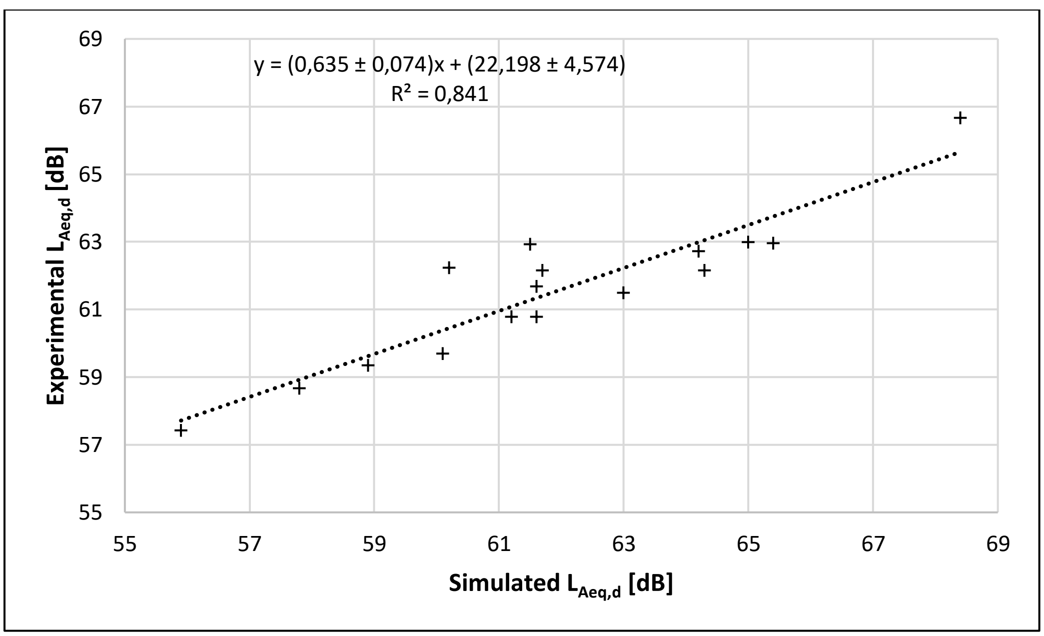


Figure A3. Validation of the noise map through linear correlation for the day period.

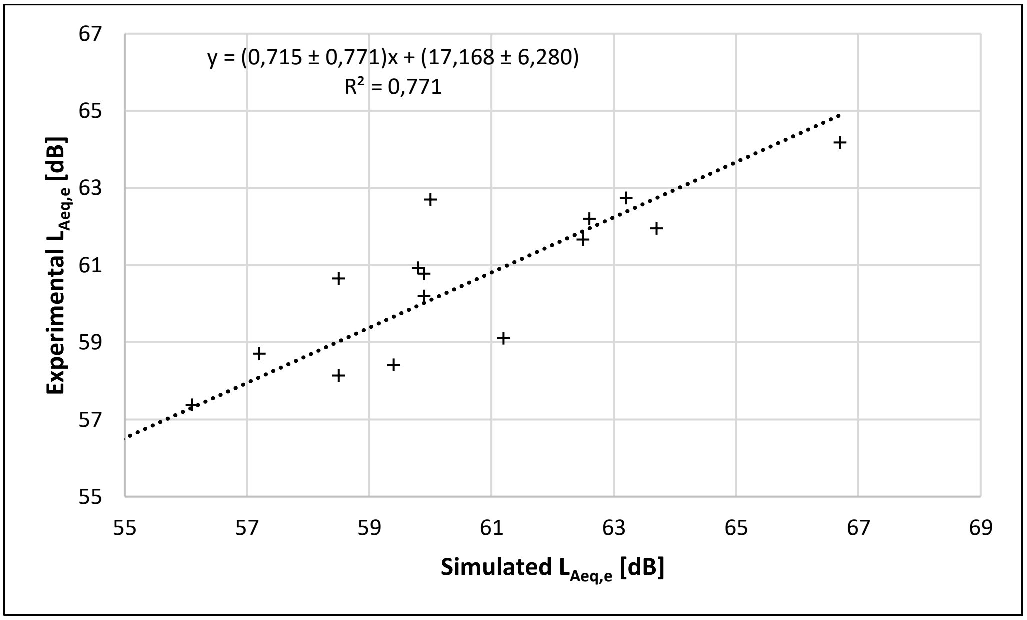


Figure A4. Validation of the noise map through linear correlation for the evening period.

B. Diagnosis of noise exposure levels according to the policy framework

Table B1. Population exposed in SZ1 to noise produced by rolled traffic in the day range.

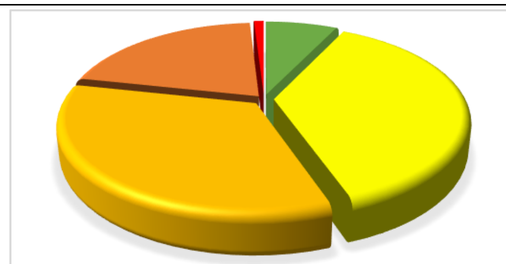
DAY (L_d)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	433	7,17	
55 - 60	2.262	37,45	
60 - 65	2.040	33,77	
65 - 70	1.247	20,64	
70 - 75	59	0,98	
> 75	0	0,00	

Table B2. Population exposed in SZ1 to noise produced by rolled traffic in the evening range.

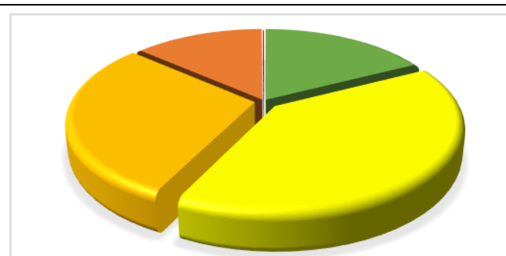
EVENING (L_e)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	1.057	17,49	
55 - 60	2.407	39,85	
60 - 65	1.757	29,09	
65 - 70	813	13,46	
70 - 75	6	0,11	
> 75	0	0,00	

Table B3. Population exposed in SZ2 to noise produced by rolled traffic in the day range.

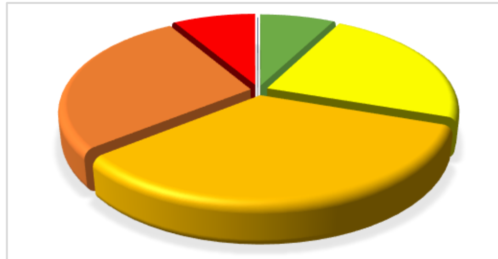
DAY (L_d)			
dBA	Exposed population (hundreds)	%	Distribution of the exposed population
< 55	771	7,64	
55 - 60	2.284	22,63	
60 - 65	3.426	33,95	
65 - 70	2.753	27,27	
70 - 75	854	8,46	
> 75	6	0,06	

Table B4. Population exposed in SZ2 to noise produced by rolled traffic in the evening range.

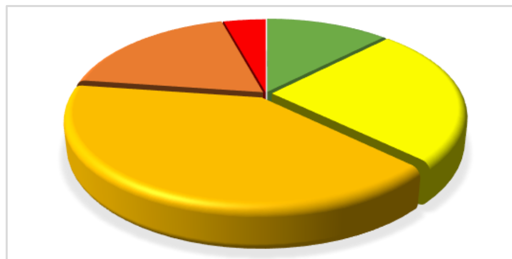
EVENING (L_e)			
dBA	Exposed population (hundreds)	%	Distribution of the exposed population
< 55	1.247	12,35	
55 - 60	2508	24,85	
60 - 65	4043	40,06	
65 - 70	1869	18,52	
70 - 75	427	4,23	
> 75	0	0,00	

Table B5. Population exposed in SZ3 to noise produced by rolled traffic in the day range.

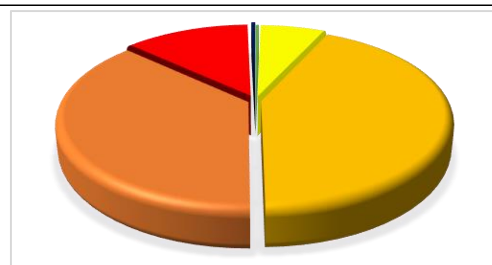
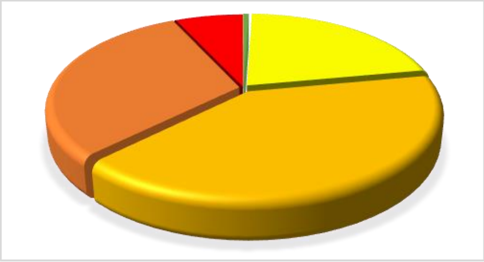
DAY (L_d)			
dBA	Exposed population (hundreds)	%	Distribution of the exposed population
< 55	22	0,33	
55 - 60	444	6,59	
60 - 65	2.889	42,87	
65 - 70	2.497	37,05	
70 - 75	860	12,76	
> 75	27	0,40	

Table 6. Population exposed in SZ3 to noise produced by rolled traffic in the evening range.

EVENING (L_e)			
dBA	**Exposed population (hundreds)**	**%**	**Distribution of the exposed population**
< 55	36	0,54	
55 - 60	1449	21,50	
60 - 65	2732	40,53	
65 - 70	2059	30,54	
70 - 75	464	6,89	
> 75	0	0,00	