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Noise pollution: causes, consequences, and solutions

Gaetano Heliot

Abstract— This Bachelor's Thesis analyzes the impact of noise pollution in the city of Barcelona, taking as a starting point the sensory contrast experienced between Amsterdam's mobility model and the acoustic reality of the Eixample district. Through direct fieldwork, specific measurements are carried out using the approved NIOSH application to evaluate real acoustic exposure across different road typologies: high-capacity roads, conventional streets, and pedestrianized axes. The ultimate goal is to assess the actual effectiveness of recent urban interventions and to propose sustainable urban management strategies that mitigate noise and protect public health in the urban environment.

Keywords— Noise pollution, urbanism, sustainable mobility, field work, public health.

Resum— Aquest Treball de Final de Grau analitza l'impacte de la contaminació acústica a la ciutat de Barcelona, prenent com a punt de partida el contrast sensorial viscut entre el model de mobilitat d'Amsterdam i la realitat sonora de l'Eixample. Mitjançant un treball de camp directe, es realitzen amidaments concrets amb l'aplicació homologada NIOSH per avaluar l'exposició acústica real en diferents tipologies de vies: carrers de gran capacitat, carrers convencionals i eixos pacificats. L'objectiu final és avaluar l'eficàcia real de les noves intervencions urbanístiques i proposar estratègies de gestió urbana sostenible que permetin mitigar el soroll i protegir la salut pública en l'entorn urbà.

Paraules clau— Contaminació acústica, urbanisme, mobilitat sostenible, treball de camp, salut pública.



1 INTRODUCTION

Noise pollution is considered to be any annoying or unwanted sound that alters the health and well-being of people and other living beings [1]. In Barcelona, according to data from the Barcelona Public Health Agency, 57% of the population is exposed to traffic noise equal to or greater than what the WHO considers harmful to health, during both daytime and nighttime periods [2]. Precisely because it cannot be seen, society has ended up normalizing exposure to very high levels of noise. We have mistakenly come to accept it as if it were a normal and mandatory consequence of living in a large city and its economic pace.

1.1 Context of the Thesis

Current cities face numerous challenges related to the quality of urban life, among which noise pollution stands out. Although issues such as air pollution have received significant attention in recent years, urban noise often remains an undervalued problem, despite its effects on the health and well-being of the population.

This thesis focuses on the study of noise pollution in the city of Barcelona, with special attention to the Eixample district, through acoustic measurements taken directly at street level. The objective is to analyze the relationship between traffic, urban structure, and the noise levels measured in different representative environments, as well as to evaluate potential mitigation strategies applicable to high-density urban areas.

1.2 Personal Motivation

The origin of this thesis stems from a personal experience. After living in Amsterdam for a period of time, returning to Barcelona revealed a stark contrast in everyday noise levels. The streets of the Eixample district, characterized by heavy traffic and constant activity, generate a much more intense

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and continuous acoustic environment.

This contrast sparked an interest in understanding to what extent noise is integrated into the city's daily life and how it varies according to street typology and mobility. Consequently, this study analyzes the situation in Barcelona from a practical perspective, based on noise measurements taken at various urban locations.

1.3 Objectives of the Thesis

- **Identify** the main sources of noise emission in the city of Barcelona and analyze their structural causes, placing special emphasis on the impact of the motorized mobility model and how the morphology of the urban fabric (such as the canyon effect in Eixample) amplifies its propagation.
- **Evaluate** the physical and psychological consequences derived from chronic exposure to noise pollution on public health and citizen well-being, taking the thresholds recommended by the World Health Organization (WHO) as a reference [3].
- **Carry out** a practical diagnosis in the Eixample district through field measurements, in order to contrast official theoretical models with the acoustic reality measured at street level on conventional axes and in pedestrianized zones.
- **Propose** strategies to reduce noise pollution through improvements in urban space organization and traffic management, considering how these factors influence daily noise levels. The objective is to identify potential actions that help reduce noise exposure and, consequently, improve people's quality of life and acoustic comfort in the urban environment.

2 THEORETICAL FRAMEWORK ON NOISE POLLUTION

2.1 Sound versus Noise

To adequately address this urban issue, it is necessary to first establish a clear distinction between the physical phenomenon and the perceived annoyance. According to the World Health Organization (WHO), community noise (also referred to as environmental, residential, or domestic noise) is defined as noise emitted from all sources except noise in the industrial workplace. The main sources of community noise include road, rail, and air traffic, industries, construction and public works [4]. Noise pollution is considered to be any unwanted sound that interferes with human activity and alters the health and well-being of people and other living beings.

2.2 Units of Measurement

In the field of acoustics, the terms dB (decibel) and dB(A) are used to measure sound pressure levels, although they have different applications. The dB measures the physical and absolute strength of a sound linearly, without considering how people perceive it. In contrast, the dB(A) is a weighted scale that adjusts to the sensitivity of the human

ear, which does not perceive all frequencies with the same intensity. While the dB indicates the total sound power, the dB(A) is used to reflect noise as we actually hear it, being the most common indicator for assessing acoustic impact on people [5]. The L_{den} is an environmental noise indicator used to represent the average noise exposure over a 24-hour period, applying an additional weighting to evening and nighttime noise to reflect a greater sensitivity to annoyance during these time slots [6]. The L_{night} indicates the average noise level during the night, expressed in dB, where the nighttime period is usually defined from 23:00 to 07:00 [7].

The difference between the L_{Amax} value and the L_{Apeak} value is as follows: the L_{Amax} value corresponds to the maximum time-weighted sound pressure level within a given measurement period, meaning it depends on the type of time weighting used in the signal calculation. On the other hand, the L_{Apeak} value represents the absolute maximum value of the instantaneous sound pressure recorded during the same period, without any time weighting. Thus, while L_{Amax} reflects a maximum, smoothed by the time, response of the measurement system, L_{Apeak} indicates the most extreme actual physical peak of the acoustic signal [8]. The L_{Aeq} or equivalent sound level: It is the data that best characterizes a noise that fluctuates over time, such as road traffic noise. It is the average energy level for a specific period of time.

2.3 WHO Thresholds

In accordance with the guidelines established by the World Health Organization through its Guidelines Development Group (GDG), strict thresholds have been set regarding environmental noise exposure with the aim of preventing harmful effects on human health. In the specific case of noise pollution derived from road traffic, the organization strongly recommends reducing average daily exposure levels below 53 decibels L_{den} , given that exceeding this threshold is directly linked to an increase in adverse health effects [9]. The equivalent sound pressure level should not exceed 30 dB(A) inside homes to avoid the onset of negative effects on sleep. Acoustic events exceeding 45 dB L_{Amax} should be limited whenever possible, and for particularly sensitive individuals, it is recommended to establish even lower thresholds [4].

2.4 Regulatory Framework in Barcelona

At the local level, these international recommendations translate into specific urban management regulations. In the Catalan capital, the Barcelona Environmental Ordinance (OMA, by its Catalan acronym) stands out as the main legal tool for regulating acoustic impact. This ordinance establishes the permitted immission and emission limits based on the so-called Acoustic Sensitivity Zones [10], adapting the maximum decibel thresholds to the different land uses (residential, healthcare, industrial, or leisure) in search of a balance between economic activity and the right to rest.

1. INCORPORACIÓ DELS USOS DEL RD1367/2007 A LES ZONES DE SENSIBILITAT ACÚSTICA

Per tal d'incorporar la zonificació per usos establerta pel Real decret 1367/2007 als mapes de capacitat acústica, s'inclou per a cada zona de sensibilitat acústica, una subclassificació en funció dels usos.

Usos del sòl
ZONA DE SENSIBILITAT ACÚSTICA ALTA (A)
(A1) Espais d'interès natural i altres
(A2) Predomini del sòl d'ús sanitari, docent i cultural
(A3) Habitatges situats al medi rural
(A4) Predomini del sòl d'ús residencial
ZONA DE SENSIBILITAT ACÚSTICA MODERADA (B)
(B1) Coexistència de sòl d'ús residencial amb activitats i/o infraestructures de transport existents
(B2) Predomini del sòl d'ús terciari diferent a (C1)
ZONA DE SENSIBILITAT ACÚSTICA BAIXA (C)
(C1) Recreatius i d'espectacles
(C2) Predomini de sòl d'ús industrial
(C3) Sectors del territori afectats per sistemes generals d'infraestructures de transport, o altres equipaments públics que els reclamin

Fig. 1: Acoustic Sensitivity Zones in Barcelona [10]

3 CAUSES OF NOISE IN URBAN ENVIRONMENTS

3.1 Road Traffic

The private vehicle is the main source of noise pollution in large cities. It is estimated that traffic is responsible for approximately 80% of the city's noise. Consequently, areas with a higher volume of traffic are where the highest acoustic values are recorded [11]. In this equation, two critical factors come into play: vehicle speed and the type of pavement. For the vast majority of vehicles, the noise derived from the interaction between the tire and the road surface tends to increase progressively with speed until, typically upon exceeding 40 km/h, it ends up surpassing the mechanical noise of the engine. Beyond this speed threshold, tire friction becomes the dominant sound source and the main component of the noise pollution generated by the moving vehicle [12].

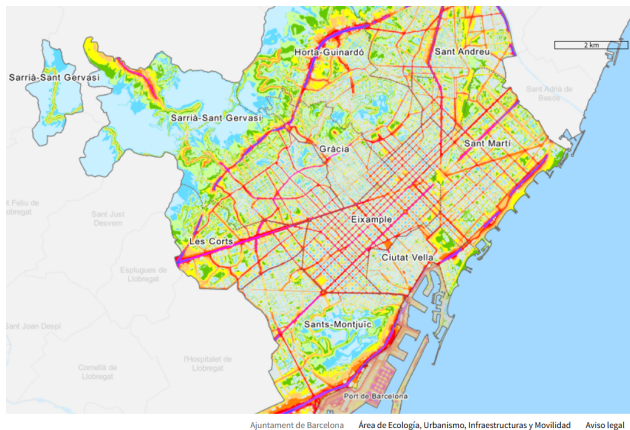


Fig. 2: Barcelona Noise Pollution Map [13]

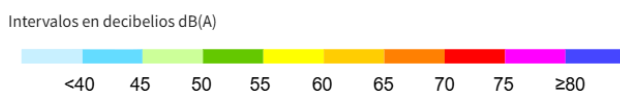


Fig. 3: Map scale

3.2 Urban Planning

The impact of noise does not depend solely on what emits it, but also on how the space propagates it. In this sense,

the urban form of Barcelona's Eixample is a clear example of what is known as the urban canyon effect. The configuration of straight and relatively narrow streets flanked by continuous high-rise facades acts as a sounding board. This geometry prevents sound waves from dissipating, causing multiple reflections between buildings that end up drastically increasing the acoustic immission levels received by homes. The shape of the building can cause variations of up to 7.0 dB(A) in the noise received by pedestrians. The facade design can reduce the average exposure at windows by 12.9 dB(A). Street geometry can enhance the positive effect of low acoustic barriers by up to 11.3 dB(A) on sidewalks [14]. It is precisely at this point where the Amsterdam model serves as a conceptual reference: urban planning that places greater emphasis on pedestrian and bicycle mobility and limits car use helps reduce this concentration and reflection of noise, ensuring a radically different soundscape. The use of bicycles in Amsterdam is predominant: it accounts for 32% of total traffic movement and is the daily means of transport for 63% of the population. The city has more bicycles than residents and maintains an extensive network of 400 km of exclusive bike lanes [15].

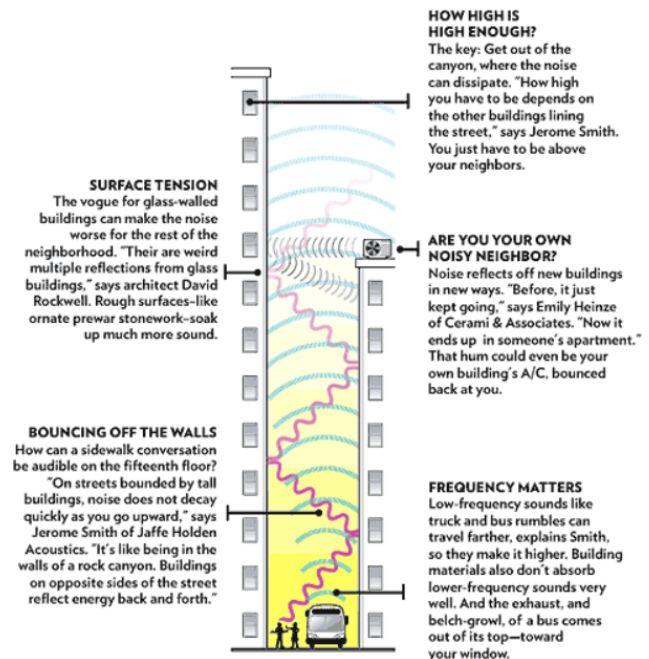


Fig. 4: Canyon effect[16]

4 CONSEQUENCES OF NOISE POLLUTION

4.1 Impacts on Human Health

Environmental noise pollution represents a critical threat to public health due to its capacity to systematically disrupt sleep. Exposure to nighttime noise triggers a biological stress response that increases the secretion of hormones such as adrenaline and cortisol, in addition to raising blood pressure and heart rate. These reactions can fragment sleep and make it shallower, causing awakenings at levels as low as 48 dB, or even bodily movements around 33 dB. In the short term, the impacts manifest the following day with drowsiness, irritability, and a decrease in cognitive performance. However, emerging evidence indicates that long-

term exposure carries serious cardiometabolic risks, such as a higher incidence of hypertension, diabetes, stroke, and coronary heart disease. Furthermore, a bidirectional relationship exists with psychiatric disorders, where insomnia acts as a predictor of anxiety and depression. In children, rest disruptions are associated with obesity and the worsening of ADHD symptoms. To protect the population, the WHO recommends a target of 40 dB for the nighttime outdoor average to prevent these harmful consequences [17].

4.2 Well-being and Quality of Life

According to the latest reports from the Environmental Noise Directive [18], more than 20% of Europeans are exposed to noise levels from transport that are harmful to health. This issue is even more severe when contrasted with the much stricter recommendations of the World Health Organization (WHO); under these criteria, the number of affected individuals rises to exceed 30%, which is equivalent to nearly one in three citizens. Among the various sources of noise pollution, road traffic stands out as the most widespread of all, as it is estimated to expose around 92 million people to levels that exceed the END threshold, set at 55 dB for the complete day, evening, and night period. This figure contrasts significantly with the impact of other modes of transport, such as rail traffic, which affects 18 million people, or airport noise, which repercussions on 2.6 million inhabitants.

In the field of environmental health hazards, transport noise consistently ranks among the top three concerns on a European scale, behind only air pollution and extreme meteorological factors such as temperature. In fact, chronic exposure to this acoustic source is a factor that contributes directly to 73,000 premature deaths per year in Europe. Likewise, it is estimated to generate annually nearly 49,000 new cases of cardiovascular diseases and some 23,000 cases of type 2 diabetes. Beyond these clinical pathologies, transport noise severely impairs the daily quality of life of the population, as nearly 16.9 million Europeans suffer from long-term chronic annoyance due to noise, and approximately 4.6 million experience severe sleep disturbances. Furthermore, recent research suggests that continuous exposure to these sound stimuli could be linked to thousands of new diagnoses of depression and dementia.

The child population is particularly vulnerable to this type of environmental pollution. It is estimated that more than half a million children in Europe experience difficulties in reading comprehension, and nearly 115,000 suffer from behavioral problems due to the direct impact of transport noise. In parallel, high noise levels have also been associated with approximately 223,000 cases of childhood overweight. Finally, this public health crisis translates into a very high socioeconomic cost for the continent. It is calculated that noise pollution caused by transport leads to the loss of 1.5 million healthy life years every year in Europe. This loss represents an annual economic impact of at least 100 billion euros, a figure that is equivalent to approximately 0.6% of the Gross Domestic Product (GDP) of the region on a sustained annual basis [19].

4.3 Impacts on the Environment

Noise pollution is a key disruptive factor for biodiversity, as it alters the behavior, physiology, and survival of numerous species in both terrestrial and marine environments. In the marine environment, underwater noise generated by shipping traffic and offshore construction interferes with the vital sounds that whales and dolphins use to communicate and navigate. On land, traffic noise fragments habitats and causes many animals to avoid suitable areas, forcing them to move to less optimal zones that reduce their reproductive success. Chronic exposure to noise has been shown to cause physiological stress in wildlife, manifested by an increased heart rate and hormonal changes that weaken their immune system. Furthermore, noise can mask the sound of predators or prey, disrupting the balance of trophic chains and even affecting entire ecosystem processes, such as pollination. Although European legislation is beginning to set limits on underwater noise, nearly one-fifth of the protected areas within the Natura 2000 network [20] are still exposed to traffic noise levels exceeding 55 dB, a threshold considered harmful to life [21].

METHODOLOGY

5.1 Analysis with NIOSH

To carry out the acoustic measurements for this work, the mobile application NIOSH Sound Level Meter was used, which was developed by the National Institute for Occupational Safety and Health [22] of the United States. This application allows the measurement of sound pressure levels using the mobile phone's built-in microphone, offering indicative data on noise pollution in different environments.

It must be taken into account that the data obtained with this application do not have the precision of a professional, approved sound level meter. Nevertheless, numerous studies and comparative tests have shown that this tool offers sufficiently reliable results for indicative and comparative analyses in non-professional environments. In this work, the measurements are used for descriptive and comparative purposes between different urban spaces in the city of Barcelona.

The objective of this analysis is not to obtain acoustic data with absolute professional precision, but rather to demonstrate that, even when using a mobile phone and an accessibly used application, the differences between various urban environments are clearly perceptible and measurable. In this way, the existing acoustic difference between pedestrianized spaces, conventional streets, and roads with intensive traffic is highlighted.

5.2 How the Measurements Were Taken

The acoustic measurements were carried out at three points within the Eixample district with diverse urban characteristics. Streets with heavy traffic (Passeig Sant Joan-Aragó), streets with conventional traffic (Bailèn-València), and pedestrianized streets (Consell de Cent-Girona) were selected to compare noise levels across different environments.

To obtain more representative data and reduce potential isolated variations, the measurements were repeated over

seven days at the same study locations. At each location, three measurements were taken: one during the morning, one during the evening, and another during nighttime hours, with the objective of observing the acoustic differences depending on the time of day.

Each measurement lasted for a duration of five minutes.

MORNING				EVENING				NIGHT			
Laeq	Girona-Consell de Cent	Bailèn-València	Aragó-Pg. Sant Joan	Laeq	Girona-Consell de Cent	Bailèn-València	Aragó-Pg. Sant Joan	Laeq	Girona-Consell de Cent	Bailèn-València	Aragó-Pg. Sant Joan
Mon.	59.4	71.5	72.2	Mon.	61.1	72.7	75.3	Mon.	55.5	68.7	69.2
Tue.	65.6	70.8	73.3	Tue.	65.4	72.7	74.2	Tue.	63.6	78.9	91.6
Wed.	60.9	70.2	72.6	Wed.	66.7	70.4	76.3	Wed.	58	72.3	68.8
Thu.	66.9	73.7	76	Thu.	67.8	68	73.2	Thu.	63	69.7	69.4
Fri.	64.1	73.7	76.1	Fri.	65.1	68.9	75.9	Fri.	64.1	71.5	73.1
Sat.	61.8	74	83.3	Sat.	64.9	71.5	76.1	Sat.	58.7	67.1	73.9
Sun.	60.6	67.7	76.5	Sun.	59.3	68.3	74	Sun.	55.6	67.3	67.8
Max. level	Girona	Bailèn	Aragó	Max. level	Girona	Bailèn	Aragó	Max. level	Girona	Bailèn	Aragó
Mon.	70.9	88.1	86.7	Mon.	73.9	89.1	90.7	Mon.	68.1	81	87.5
Tue.	77.1	83.3	94.4	Tue.	81.4	90.1	84.9	Tue.	68.9	83.7	106.9
Wed.	82	88.2	89.2	Wed.	84	85.6	89.3	Wed.	73.6	88.1	82.4
Thu.	86.8	85.3	94.7	Thu.	90.1	83.4	84.7	Thu.	85.2	81.6	81.8
Fri.	80	92	92.1	Fri.	76.4	85.9	97.6	Fri.	88.5	85.5	83.6
Sat.	72.8	94.6	107.6	Sat.	83.2	86	88.9	Sat.	70.9	80.5	91
Sun.	72.1	87.7	93.6	Sun.	71.2	81.1	84.6	Sun.	73.9	79.3	85.5
Lcpea k	Girona	Bailèn	Aragó	Lcpea k	Girona	Bailèn	Aragó	Lcpea k	Girona	Bailèn	Aragó
Mon.	91.1	105.9	103.5	Mon.	96.2	107.8	114.6	Mon.	97	99.7	102.5
Tue.	98.7	108.9	108.5	Tue.	92.2	108.3	105.5	Tue.	71.4	89.2	108.9
Wed.	107.2	101.1	109.7	Wed.	107.2	111.4	111.4	Wed.	103	106	101.2
Thu.	115.8	106.5	105.6	Thu.	114.9	97.5	101.7	Thu.	110.2	98.2	101.2
Fri.	102.9	101.4	108.6	Fri.	101.5	102.3	114.1	Fri.	96.3	101.5	101.6
Sat.	101.6	112.3	114.5	Sat.	94.3	102.3	105.1	Sat.	99	95.7	111
Sun.	98.2	111.1	112.5	Sun.	95.6	101	99.4	Sun.	91.2	97.3	114.9

Fig. 5: Street Noise Measurements in dB(A)

In parallel, the noise level in my bedroom, located on Passeig Sant Joan near Gran Via, was measured over five days during nighttime hours to observe whether the level recommended by the WHO is exceeded. During the measurements, the mobile device was kept in a stable position without any movement to avoid alterations in the results.

6 RESULTS

To facilitate the reading and interpretation of the results, I have created tables with the collected data. These visual tools allow a direct look at the acoustic conditions recorded during the field measurements.

The results are presented by differentiating between the various types of environments analyzed, such as zones with high traffic intensity, conventional streets, pedestrianized spaces, and the measurements taken inside the home.

It is observed that, across all time slots, the measurements recorded on the pedestrianized axes remain systematically lower than those on conventional axes. The Passeig Sant Joan-Aragó axis clearly stands out as the loudest road of the entire study.

Overall, the results show a clear relationship between traffic intensity and noise level.

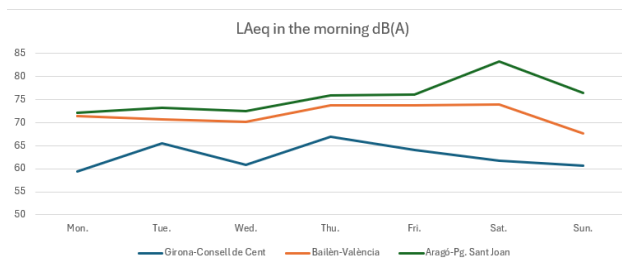


Fig. 6: Morning measurements

Regarding the measurements taken inside the bedroom, the LAmax values exceeded the threshold recommended by

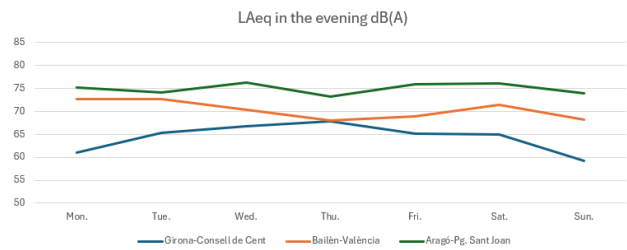


Fig. 7: Evening measurements

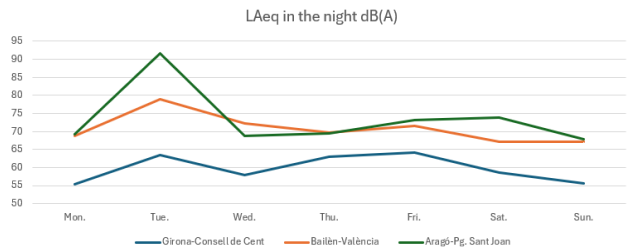


Fig. 8: Night measurements

the WHO during every analyzed nighttime period. The fact that these limits are surpassed even in short-duration samplings (only 5 minutes) suggests that homes located near high-intensity road axes, such as Passeig de Sant Joan or Gran Via, rarely enjoy nights free of noise peaks exceeding 45 dB(A).

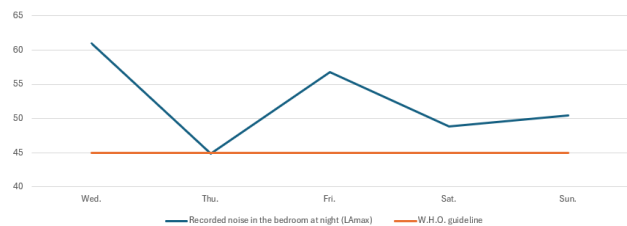


Fig. 9: Recorded noise in the bedroom at night (LAmax)

7 MITIGATION STRATEGIES

Throughout recent decades, several cities around the world have implemented measures aimed at reducing noise pollution and improving the quality of life of their inhabitants. These actions have addressed the problem from different perspectives, including traffic reorganization, the transformation of urban space, the introduction of new technologies in transport, and the incorporation of natural elements into the urban environment. This section presents some of the most prominent strategies that have proven useful in reducing noise levels in cities.

7.1 Street pedestrianization

One of the most effective measures to reduce urban noise is the progressive pedestrianization of streets, especially in residential areas. This involves reducing vehicle speeds, limiting through traffic, and providing more space for pedestrians.

At the analyzed locations, the streets with lower traffic intensity showed clearly lower noise levels, a fact that re-

inforces the importance of this type of intervention. The reduction of vehicles not only decreases noise but also improves the overall quality of public spaces.

7.2 Electrification of the Urban Services Vehicle Fleet

Urban services vehicles, such as buses or waste collection trucks, represent one of the primary sources of noise pollution in cities, an impact that is especially critical during nighttime or early morning hours. The progressive replacement of these fleets with electric vehicles not only eliminates pollutant emissions at the source but also drastically reduces the noise and vibrations associated with stop-and-go cycles. This technological transition therefore becomes a key public health tool for mitigating noise pollution during the population's rest periods.

One of the most significant recent examples is the mass deployment of electric garbage trucks in the city of Copenhagen. The municipal waste management company Amager Resource Center (ARC), in collaboration with the industrial vehicle manufacturer Scania, carried out a strategic renovation of its fleet by incorporating an initial batch of 86 fully electric collection trucks. This measure is part of the Danish capital's ambitious goal to become a carbon-neutral city. [24]

This transition toward emissions-free and noise-free urban services is not an isolated phenomenon, nor is it exclusive to the European market or heavy-duty vehicles. Various global manufacturers are already commercializing fleets adapted to different operational needs. A clear example is the brand RIZON Truck (a division of the Daimler Truck group), which actively operates in municipalities and waste management companies across the United States and Canada. Unlike traditional heavy models, RIZON has focused on the medium-duty electric truck segment (Class 4 and 5), demonstrating that electric technology is scalable to different types of urban sanitation vehicles.

Efficiency in urban operational cycles (stop-and-go): Given that a collection truck can make hundreds of stops in a single day, the regenerative braking technology of these vehicles takes on vital importance. This system not only extends the lifespan of mechanical brakes, thereby reducing maintenance costs, but also converts the kinetic energy from continuous braking into electrical energy that is fed back into the battery, optimizing the vehicle's range in residential environments. RIZON trucks offer remarkable range and efficiency within Class 4 and 5 medium-duty service vehicles, achieving up to 155 miles of range under standard test conditions. [25]

Another reference benchmark that demonstrates the maturity and long-term viability of this technology is the case of the Netherlands. The waste management company HVC, responsible for refuse collection in 52 Dutch municipalities, made the strategic decision to invest in electric trucks in 2018, becoming one of the pioneers in the sector. By incorporating models such as the Volvo FE Electric, HVC has consolidated a large-scale operation that validates the performance of these vehicles in real-world environments for nearly a decade.

Currently, 20% of the company's 400 vehicles run on electricity, and the nature of their activity has made the tran-

sition relatively straightforward. [26]

"Range is not an issue for us, as we only cover a maximum of 100 km per day. After the working day, the vehicles remain parked for an average of 14 hours, which is more than enough time to fully charge them."

The difference in acoustic emissions is noticeable and can be objectively quantified. The following table shows the advantages that electric technology presents compared to conventional systems:

Operation Mode	Diesel Bus Noise Level	Electric Bus Noise Level	Human Perception
Idling (Stationary)	75 - 80 dB	~0 dB (Silent)	Electric is virtually silent at stops.
Acceleration (0-30 km/h)	80 - 85 dB	60 - 65 dB	Diesel is twice as loud perceptually.
Cruising (50 km/h)	85+ dB	70 - 75 dB	Tire noise dominates for both.

Fig. 10: Noise Levels Between Diesel and Electric Buses [27]

7.3 Vegetation as a Noise Reduction Element

The incorporation of urban vegetation can help partially reduce the perception of noise, especially on streets with high traffic density. Although it does not act as an absolute barrier, the presence of trees and green zones contributes to softening sound propagation and improving the acoustic sensation of the environment.

Furthermore, these elements have additional positive effects on urban comfort, such as reducing heat and improving the general well-being of public spaces. The published results regarding the effectiveness of trees as acoustic barriers vary considerably. Nevertheless, a study by Huddart (1990) shows that, in some cases, noise can be reduced by up to 6 dB over a distance of 30 meters when the vegetation is particularly dense.

Other researchers, such as Leonard and Parr (1970) and Reethof (1973), observed that a dense strip of trees and shrubs between 15 and 30 meters wide could reduce sound levels by 6 to 8 dB. Similarly, Cook and Van Haverbeke (1972) recorded reductions of between 5 and 10 dB in wooded strips of comparable dimensions.

Research also indicates that wide plantings, roughly 30 meters wide, consisting of tall, dense trees combined with soft ground surfaces, can reduce the perception of noise by at least 50%. The use of vegetation as an acoustic barrier can contribute to reducing noise propagation, but its effectiveness depends on several factors related to its placement, density, and composition. Among the most important aspects, the following stand out: [28]

- Noise reduction is more effective when the emitting source is completely hidden from the line of sight.
- Plant barriers should be located as close to the noise source as possible.
- To achieve significant noise reductions, it is necessary to deploy wide strips of trees and shrubs with a high density.
- The effectiveness of the barrier is closely related to the density of trunks, branches, and foliage.
- To maintain acoustic attenuation capacity throughout the year, it is recommended to use evergreen species or a combination of evergreens and conifers.

- Soft ground absorbs sound more efficiently than hard surfaces. Soil preparation prior to planting and the addition of organic matter can also contribute to reducing noise while the vegetation develops.

7.4 Sound-Absorbing Pavement

Another element that can contribute to noise reduction in urban environments is the use of sound-absorbing pavements. These are types of asphalt designed to reduce the noise generated by the contact between vehicle tires and the road surface, which is one of the primary sources of noise pollution on high-traffic roads.

This type of pavement allows for a slight decrease in perceived noise levels, especially when compared to conventional asphalt, and its effect is more noticeable on roads with moderate or high speeds.

Although it does not eliminate the problem of urban noise, it can contribute to reducing it in a complementary manner within a broader set of measures, especially on streets where it is not possible to significantly reduce traffic volume.

The noise generated by the contact between the tires and the pavement stems mainly from three phenomena: air compression, tire tread vibration, and resonance within the pavement structure [29]. Sound-absorbing asphalt minimizes each of these effects through its design:

- **Porosity absorption:** porous mixtures allow compressed air to pass into interconnected voids instead of bouncing outward, thus reducing sound propagation.
- **Material damping:** additives such as rubber or polymers absorb part of the vibrational energy before it is transmitted to the environment.
- **Texture control:** a carefully designed aggregate structure smoothens the airflow, limiting sudden pressure changes that generate high-frequency noise.

Low-noise pavements can reduce noise pollution by 6 to 8 decibels when new, and by approximately 3 decibels at the end of their lifespan. From an acoustic standpoint, a reduction of 3 decibels is equivalent to a reduction of approximately half the traffic volume.

7.5 Examples of street pedestrianization in Barcelona

- **Poblenou Superblock:** The Poblenou superblock was one of the first major pedestrianization interventions implemented in Barcelona. In September 2016, the Poblenou Superblock was inaugurated within the perimeter formed by Badajoz, Pallars, Llacuna, and Tànger streets, spanning the neighborhoods of Poblenou and Parc i la Llacuna del Poblenou. The implemented measures include changes in mobility (such as traffic restrictions in certain zones), the installation of new urban furniture, and an increase in greenery [2].
- **Sant Antoni Superblock:** The reorganization of traffic and the expansion of pedestrian spaces around the Sant Antoni market contributed to creating a quieter environment with lower acoustic intensity compared



Fig. 11: Pedestrianized Street

to other zones with conventional traffic. Proof of this is the analyzed behavior of this variable following the implementation of the Sant Antoni Superblock, for which sound level measurements are available prior to and after its implementation at the intersection of Comte Borrell and Tamarit streets. The results demonstrate that the average daytime noise decreased by 3.5 decibels in the months following the intervention, representing a 5.2% reduction. Nighttime noise decreased during certain months and increased in others, maintaining overall levels similar to those prior to the intervention. [2]

- **Example pedestrianized streets:** The transformation of several streets in the Eixample district, such as Consell de Cent, into pedestrian-priority axes has led to a reduction in motorized traffic and an improvement in acoustic comfort in these zones. A recent example of the effects of urban pedestrianization on noise pollution can be found in a study conducted by Samuel Nello-Deakin and Xavier Delclòs-Alió on the new green axes of the Eixample. Using data from seven permanent acoustic monitoring stations in Barcelona, the authors analyzed the changes in noise levels following the transformation of these streets in 2023. The results show an average reduction of 3.1 dB in the noise level over 24 hours, a significant decrease considering that the decibel scale is logarithmic. Furthermore, the study highlights that the reduction in motorized traffic not only entails a decrease in noise levels but also a transformation of the soundscape, with a greater presence of sounds associated with pedestrian activity. Complementarily, a survey conducted among 1,211 residents showed that people living on pedestrianized streets use their balconies and street-facing rooms more frequently, suggesting a more positive perception of the acoustic environment and an im-

provement in their quality of life [30].



Fig. 12: Pedestrianized street

- **Glòries Project:** The transformation of Plaça de les Glòries has been one of the most important urban planning interventions in Barcelona in recent decades. The undergrounding of a significant portion of the traffic and the creation of new green spaces and pedestrian zones have contributed to reducing the presence of surface vehicles and improving the environmental quality of the surroundings. This intervention has made it possible to reclaim public space for citizens and generate a more pleasant environment from an acoustic perspective. Regarding acoustic levels, in the section of Gran Via where vehicle circulation was placed underground, noise values decreased from 74 dB to 65 dB. This reduction represents a significant improvement in the acoustic quality of the area, bringing it down to levels comparable to those of spaces primarily designated for pedestrians [31].

8 CONCLUSIONS

This Bachelor's Thesis has provided a comprehensive approach to the issue of noise pollution in the city of Barcelona, combining the analysis of official data with a practical, on-the-ground methodology in the Eixample district. Based on the established objectives and the research conducted, the following key conclusions can be drawn:

- **Traffic as a Critical Factor and the Canyon Effect:** The results of this study confirm that the private vehicle is the primary driver of urban noise, especially on roads where speeds exceed 40 km/h, at which point tire friction becomes the dominant source. This reality is structurally aggravated in the Eixample district due to the canyon effect of its urban layout, where the conti-

nity and height of the facades act as a sounding board that prevents the dissipation of sound waves.

- **Empirical Validation of Urban Planning Interventions:** The field measurements suggest that urban design plays a significant role in shaping the acoustic environment and its potential health impacts. While the high-intensity axis (Passeig de Sant Joan – Aragó) systematically records the highest and most harmful levels, pedestrianized zones such as the new green axes of Consell de Cent show a remarkable acoustic reduction. This validates the effectiveness of models like the Superblocks (Superilles) as direct tools for public health.
- **Exceeding WHO Thresholds and Domestic Vulnerability:** The data collected inside the dwelling during nighttime hours reveal a worrying situation: the L_{Amax} values systematically exceed the 45 dB limit recommended by the World Health Organization to guarantee restorative sleep. This chronic exposure to sound peaks, even in short-duration sampling, highlights that the population residing near major road axes suffers a real risk of developing cardiovascular problems, stress, and sleep disturbances.
- **Toward Comprehensive and Sustainable Urban Governance:** The conceptual contrast with the Amsterdam model demonstrates that the transition toward a quiet city requires comprehensive planning that firmly prioritizes active mobility. However, as future sustainable city managers, the ultimate solution does not rely exclusively on traditional urban planning (such as sound-absorbing pavements or major structural undergrounding), but rather on the adoption of strategic fleet transformation policies. The progressive electrification of essential urban services (such as municipal buses and waste collection trucks) must become a priority to reduce acoustic impact at its root, turning these public management measures into crucial factors to effectively guarantee the right to rest and long-term health in Barcelona.

9 AWARENESS POTENTIAL AND FUTURE HORIZONS

Beyond technical results and data analysis, this Bachelor's Thesis is born with the vocation of being a tool for social transformation and public awareness. Noise pollution is an invisible enemy that we have often normalized as an inevitable consequence of urban life, forgetting the real impact it has on our physical and mental health.

The following lines of continuity are proposed for the future of this project:

- **Public outreach and awareness-raising tool:** The main objective of expanding this work in the future is to bring these evidences to the general public. Clearly and visually explaining how noise peaks affect nighttime rest should serve to make society realize that noise is not just a minor nuisance, but a critical public health issue.

- **Visibility of viable alternatives and solutions:** This study does not intend to fall into pessimism, but rather to demonstrate empirically that real and applicable alternatives exist. The contrast between conventional and pedestrianized axes serves as proof that, with political will and proper urban planning, it is completely possible to transform Barcelona into a quieter, friendlier, and more livable city.
- **Promotion of debates on the mobility model:** The aim is for the conclusions of this research to serve as a baseline to spark community debates at the local level (neighborhood associations, schools, or local entities). Making it visible that changing the urban model brings immediate benefits to acoustic comfort is key to breaking resistance toward pedestrianizing measures and demanding a transition to a model with a reduced presence of motorized vehicles.

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APPENDIX

A.1 Study area map



Fig. 13: Study area map

A.2 NIOSH measurements samples



Noise measurement report

Date: 1/6/26, 10:56

Operator: Gaetano Heliot

Place: Aragó-Pg. Sant Joan

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	72.2 dB
Max. level	86.7 dB
LCpeak	103.5 dB
TWA	44.2 dB
Dose	0.0 %
Projected dose	0.1 %

Notes

Fig. 14: Morning measurement in Aragó-Passeig Sant Joan



Noise measurement report

Date: 1/6/26, 10:49

Operator: Gaetano Heliot

Place: Valencia-Bailèn

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	71.5 dB
Max. level	88.1 dB
LCpeak	105.9 dB
TWA	42.8 dB
Dose	0.0 %
Projected dose	0.0 %

Notes

Fig. 16: Morning measurement in València-Bailèn



Noise measurement report

Date: 1/6/26, 10:39

Operator: Gaetano Heliot

Place: Concell de Cent-Girona

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	59.4 dB
Max. level	70.9 dB
LCpeak	91.1 dB
TWA	dB
Dose	%
Projected dose	%

Notes

Fig. 15: Morning measurement in Girona-Consell de Cent



Noise measurement report

Date: 6/6/26, 00:51

Operator: Gaetano Heliot

Place: In my room

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	34.9 dB
Max. level	56.8 dB
LCpeak	76.6 dB
TWA	dB
Dose	%
Projected dose	%

Notes

Fig. 17: Night measurement in my room



Noise measurement report

Date: 1/6/26, 20:49

Operator: Gaetano Heliot

Place: Aragó-Pg. Sant Joan

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	75.3 dB
Max. level	90.7 dB
LCpeak	114.6 dB
TWA	52.6 dB
Dose	0.1 %
Projected dose	0.5 %

Notes



Noise measurement report

Date: 1/6/26, 21:05

Operator: Gaetano Heliot

Place: Concell de Cent-Girona

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	61.1 dB
Max. level	73.9 dB
LCpeak	96.2 dB
TWA	dB
Dose	%
Projected dose	%

Notes

Fig. 18: Evening measurement in Aragó-Passeig Sant Joan

Fig. 20: Evening measurement in Girona-Consell de Cent



Noise measurement report

Date: 1/6/26, 20:56

Operator: Gaetano Heliot

Place: Valencia-Bailèn

Measurement results

Measurement time (hh:mm:ss)	00:05:00
LAeq	72.7 dB
Max. level	89.1 dB
LCpeak	107.8 dB
TWA	49.1 dB
Dose	0.0 %
Projected dose	0.2 %

Notes



Noise measurement report

Date: 2/6/26, 00:14

Operator: Gaetano Heliot

Place: Aragó-Pg. Sant Joan

Measurement results

Measurement time (hh:mm:ss)	00:05:05
LAeq	69.2 dB
Max. level	87.5 dB
LCpeak	102.5 dB
TWA	42.9 dB
Dose	0.0 %
Projected dose	0.0 %

Notes

Fig. 19: Evening measurement in València-Bailèn

Fig. 21: Night measurement in Aragó-Passeig Sant Joan

A.3 All NIOSH measurements

Due to space and formatting constraints, the complete set of measures obtained via the NIOSH Sound Level Meter application during the fieldwork phase is hosted externally:

[Zenodo Repository](#)