



MADRID
inter.noise 2019
June 16 - 19

NOISE CONTROL FOR A BETTER ENVIRONMENT

Management Noise Network of Madrid City Council

Garrido Salcedo, José Carlos¹
Ayuntamiento de Madrid
Madrid, Spain

Mosquera Lareo, Blanca María²
EMS Brüel & Kjær
Madrid, Spain

Echarte Puy, Julen³
EMS Brüel & Kjær
Madrid, Spain

Sanz Pozo, Roberto⁴
EMS Brüel & Kjær
Madrid, Spain

ABSTRACT

Madrid City Council is one of the most active cities fighting against noise, thanks to the Monitoring Network of Acoustic Contamination that grants knowledge and control over the noise in a city with more than 3.5 million inhabitants. The innovative approach in the development of procedures to carry out noise measurements with the most advanced and reliable means at all times is to be highlighted.

The Acoustic Pollution Monitoring Network is made up by three types of instrumentation: Permanent Network formed by 31 stations in charge of the control and continuous monitoring of the existing noise levels in the city; Mobile Network formed by 16 mobile stations that allows analysing the noise levels in some points of the city that requires a specific study; and SADMAM formed by 5 instrumented vehicles that allows recording noise levels anywhere in the city.

The City of Madrid implemented this pioneering monitoring network that enables, through the combination of measurements and calculations, the categorization of the emission of the roads in the city or detecting and improving areas with leisure noise contamination, for which different plans and strategies are elaborated, which have managed to reduce the noise in different areas of the city.

Keywords: Noise, Monitoring, Analysis

I-INCE Classification of Subject Number: 60, 71, 72, 74, 75, 76

1. INTRODUCTION

Madrid, with an area of 604 km², is the largest city in Spain, located in the central area of the Iberian Peninsula. The city has more than 3 million inhabitants that are distributed in the 21 districts in which the urban area is administratively divided.

¹ garridosjc@madrid.es

² blanca.mosquera@emsbk.com

³ julen.echarte@emsbk.com

⁴ roberto.sanz@emsbk.com

The city of Madrid, capital of Spain and centre of the main communication networks of the country, gathers numerous infrastructures such as highways, railway lines and one of the most important airports in Europe.

Nowadays, the inhabitants of Madrid show a growing concern for environmental conditions, amongst which air pollution stands out, which is indicated to be the second of the city's main problems. In this ranking, noise is among the top ten, which has led to the fact that, at present, a new city paradigm is being worked on based on numerous initiatives in environmental and mobility matters, aimed at guaranteeing a healthy urban environment for its neighbours and visitors.

Madrid City Council, aware of this situation, has set the necessary measures and initiatives in motion to reduce pollution in those areas of the city affected by high noise levels, as well as preserving quiet areas. Among these initiatives, there are actions such as the first noise maps, the declaration of environmental protection figures in the most affected areas of the city or the implementation of one of the most important urban noise monitoring networks in the world. All these initiatives show the pioneering and innovative nature of the Madrid City Council in the fight against noise, by always opting for innovative planning in the procedures, as well as for equipping itself with the most advanced and reliable means and instrumentation.

In this work, for more than 15 years, the City Council has had the experience of EMS Brüel & Kjær, which provides a technical service to the municipality both in human resources and in instrumentation for measurement campaigns.

2. MADRID CITY COUNCIL MONITORING NETWORK

The control and monitoring of the existing noise levels in the city is one of the fundamental tools in the management of noise pollution and, in this sense, Madrid is a pioneering and exemplary city, which has been equipped with one of most complete noise monitoring networks in the world. Over the years, it has implemented the Acoustic Pollution Monitoring Network, formed by:

- **Permanent Network:** Composed of 31 stations. It is responsible for the control and continuous monitoring of noise levels in the city.
- **Mobile Network:** Composed of 16 mobile stations. It allows to analyse noise levels in those points of the city that require a particular study.
- **SADMAM:** Composed of 5 instrumented vehicles. It allows measuring noise levels at any point in the city, multiplying the number of measurements for the preparation of the Strategic Noise Map.

2.1. Permanent Network

In 1994 a network of 6 stations was installed. This has been extended and updated with more modern instrumentation adding to the 31 stations that make it up today, their location is shown in the following image.

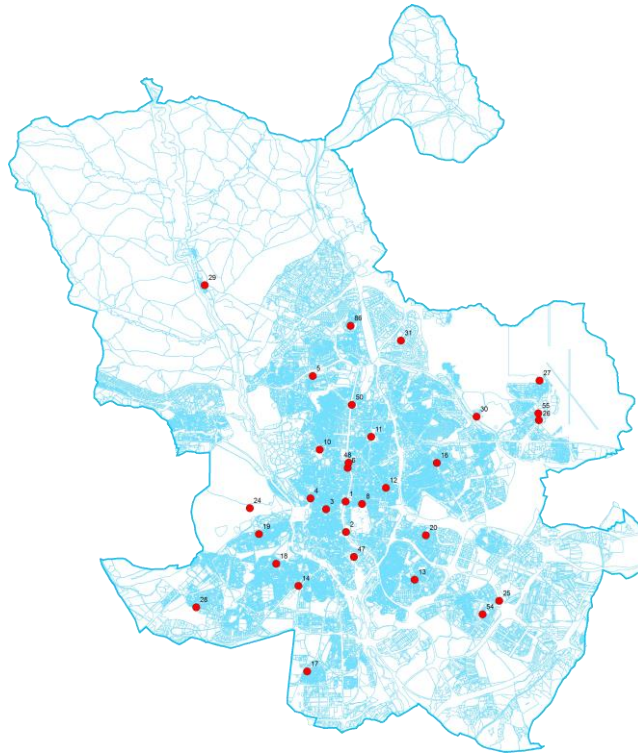


Figure 1. Location of the 31 stations that make up the Permanent Network.

This network is used to determine the temporal evolution of environmental noise levels in the vicinity of each station. Although it is mainly measured in environments where the main focus of noise is road traffic, there are also stations located in environments where the predominant noise focus is different from traffic, such as tertiary/commercial activity. The simplified structure of the network is shown in the following image:

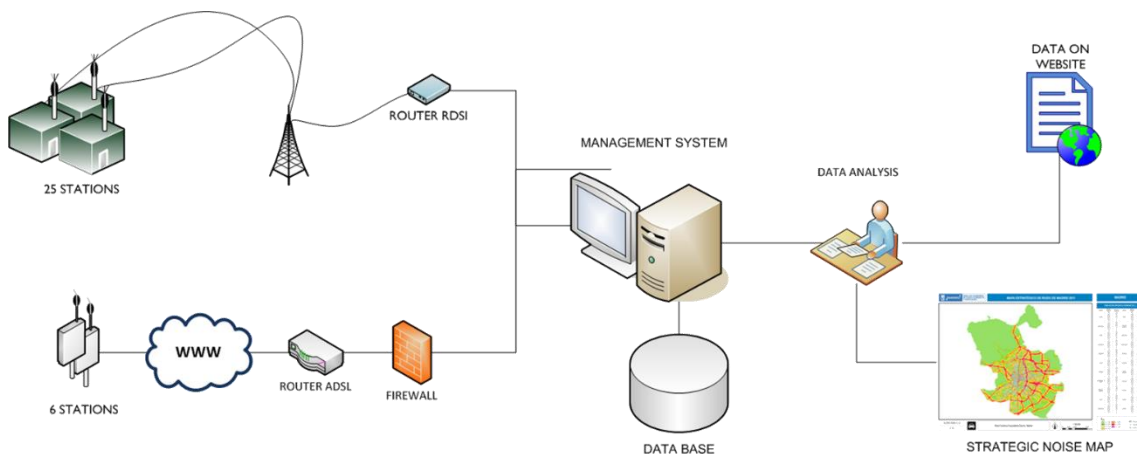


Figure 2. Structure of the Permanent Network.

- Noise monitoring terminals installed on staffs or booths, sharing in some cases location with air quality stations.
- Data is sent to the Data Processing Centre.
- Data is analysed and validated before becoming part of the data history
- Data is published on a daily basis on the municipal website.

2.2. Mobile Network

The Mobile Network consists of 16 terminals monitoring noise and it is used for:

- Taking measurements due to environmental noise problems.
- Developing the leisure cartography.
- Supporting the preparation of the Strategic Noise Map.
- Collaboration from neighbours is required for the temporary installation of the noise monitor.

The structure of the Mobile Network is:

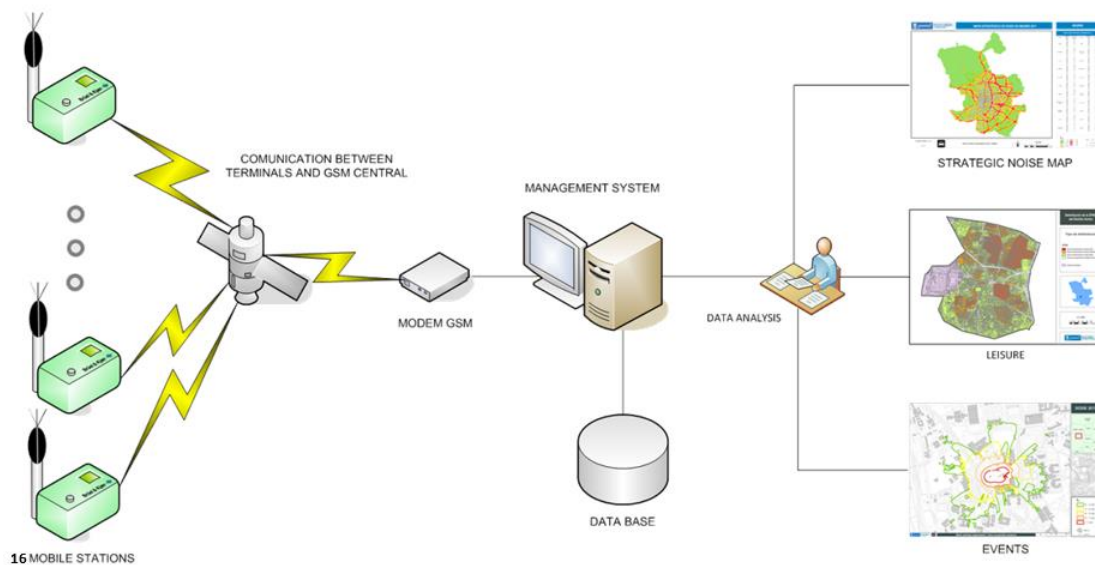


Figure 3. Structure of the Mobile Network.

- The stations are installed, temporarily, in the required locations.
- The technician downloads the measurements values for analysis.
- The corresponding report is prepared, communicating the result to the interested parties.

2.3. SADMAM

In order to have a measurement system that allows increasing the number of measurements in a reliable way, necessary to elaborate the Strategic Noise Map, small vehicles are acoustically instrumented, in which:

- A mast is installed to be able to measure at 4 m in height, following the recommendations of the current legislation.
- A GPS is incorporated to georeference the measurement.
- Measures of at least 5 hours are carried out.

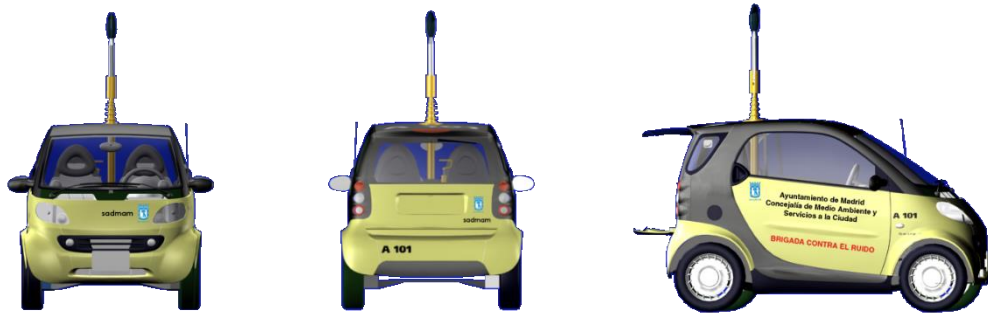


Figure 4. Vehicles of SADMAM.

The structure of the SADMAM is:

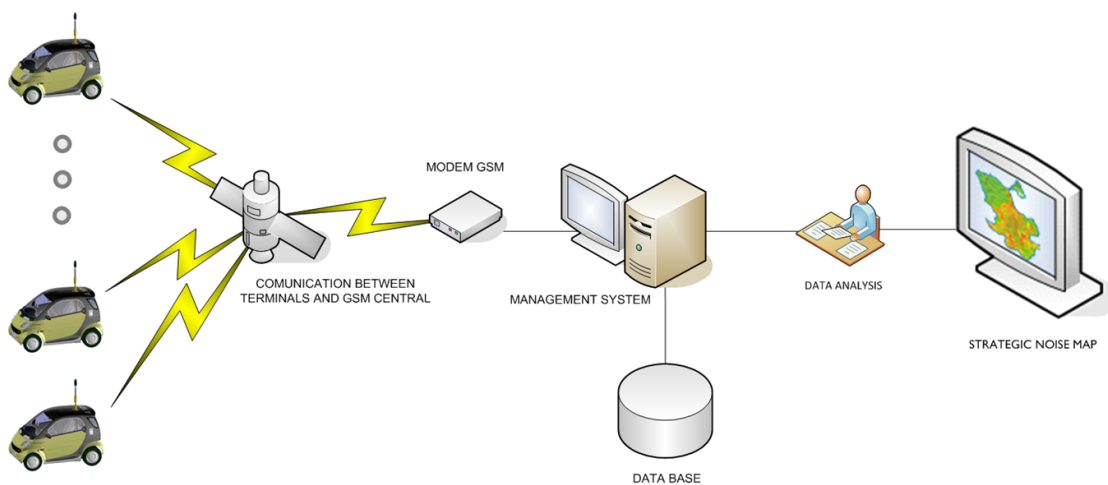


Figure 5. Structure of SADMAM.

- These vehicles, thanks to their size and versatility, provide measurements of environmental noise at any point in the city, and as a consequence, extensive sampling and a good distribution of the different areas of the city.
- The measured values are sent to the Data Processing Centre where they are validated.

All monitoring terminals that the Madrid City Council uses for the different monitoring networks presented in this same point, are equipped with Brüel & Kjær analysers, more precisely models 4435, 4441, and 2250.

It should be emphasized, despite the difference in dates of manufacture of these models, where the first 4435 was installed in 1994, and the last 2250 in 2011, they are all analysers Type 1/Class 1 as it is expressed the article 30 of the RD 1367/2007. This instrumentation continuously registers the existing environmental noise values (every half second or every second depending on the model) and automatically integrates the noise values corresponding to each hour. In addition, the units automatically perform a double verification of calibration every 6 hours, both electrical by load insertion, and acoustic, by applying a reference tone to the microphone.

3. APPLICATION OF A NOISE MONITORING NETWORK

The City Council of Madrid has always been aware of the importance of noise for citizens. In compliance with current legislation, both state and European, the City together with EMS Brüel & Kjær have been developing, for over 15 years, various projects that are the fundamental tools for the management and control of environmental noise.

To do this, the Acoustic Pollution Monitoring Network explained above has been used in order to improve the quality and result of the projects carried out by the municipality.

3.1. Information to the citizen

In today's society, a larger and more updated amount of information about everything that happens around us is demanded, a more than evident topic when it comes to sensitive issues related to health, such as the case of noise pollution in the cities. For this reason, one of the most important issues in the Management of Environmental Noise that an administration should anticipate is to have procedures and information mechanisms aimed at making the existing situation known to citizens.

The path in the fight against environmental noise in the City of Madrid has highlighted the importance of considering the citizenship both when proposing solutions and when implementing measures against noise.

In this sense, the European Directive establishes that information must be easily accessible and organized in a way that is clear and intelligible, in order to fulfil its purpose of informing. The Directive refers to the publication of the data contained in the strategic noise maps, which must be prepared periodically every five years, and this is precisely where having a monitoring network plays a fundamental role since it allows to have updated information more frequently. In particular, the Permanent Network allows daily availability of the noise indicators' values, corresponding to each of the day intervals established in the legislation, in the vicinity of each station in the network.

For more than 20 years, the Madrid City Council has published on a daily basis the data of the Permanent Network stations, so that anyone interested in knowing the existing noise levels can access them through the website of the City of Madrid.

In addition, the City Council goes one step beyond the disclosure of daily values and publishes the historical values of the noise indicators registered in the network since 1998, so that anyone interested can download them to analyse them.

3.2. Characterization of roads for Strategic Noise Maps

Noise maps allow the representation of an existing or predicted acoustic situation based on a noise indicator, so that compliance with the Acoustic Quality Objectives can be assessed, as well as quantifying the number of people affected and evaluating which are the most appropriate actions to improve the acoustic situation.

The City Council of Madrid, a pioneer in the development of noise maps, has been mapping the acoustic situation in the city for more than 30 years, with the aim of:

- Knowing the noise levels in each point of the city.
- Making noise data available to citizens.
- Serving as the basis for the preparation of the Action Plan.
- Serving as a tool for territorial planning in new urban developments.

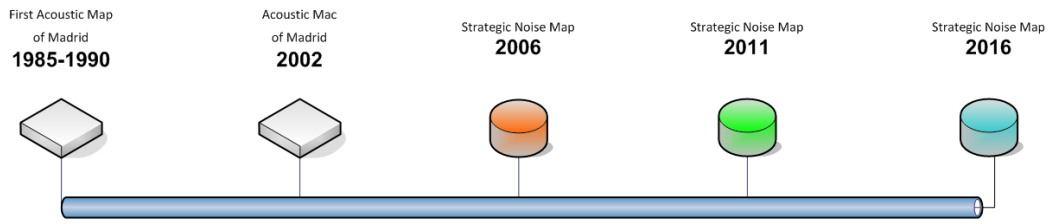


Figure 6. Milestones of noise mapping in the City of Madrid.

Both the City Council and EMS Brüel & Kjør have extensive experience in acoustic mapping, an example of this is the first Strategic Noise Map (SNM) of Madrid 2006 that shows the noise levels due to road traffic. After 5 years, and in order to update the changes that happened in the municipality, SNM 2011 was developed, and recently, SNM 2016 has been approved, which shows the most updated acoustic situation in the city.

The municipal technical services, aware of the problem of the calculation model for roads established in the legislation applied in urban environments, developed a procedure with the objective of increasing the reliability and representativeness of the results of the simulation, using the recorded noise data in the stations of the network.

To perform the MER, the characteristics and data of the three types of monitoring networks presented above are gathered. First, the long-term measurements of the Permanent and Mobile Networks are used to characterize the time variations of the roads. Around 400 measurements were analysed with the objective of classifying the acoustic behaviour of the different types of roads existing in Madrid, that is, the time evolution of the noise levels hour by hour, throughout the day in each of the most common acoustic environments in the city.

In this way, the typical acoustic emission was characterized for each of the streets of the municipality, analysing the results of the measurements and the characteristics of the environment in which each one was carried out according to the type of road, the intensity of the traffic that supports, the function of the street, the morphology of the street, and so on. The classification is shown below:

Type	Category
I	Exclusive residential
II	Residential
III	Residential Distributor
IV	Neighbourhood Distributor
V	District Distributor
VI	Major roads
VII	M – 30 and access to highways
VIII	Highways

Table 1. Classification of streets.

The following image shows, as an example, the curves obtained for two specific types of streets: Type I (residential), and Type VII (M-30).

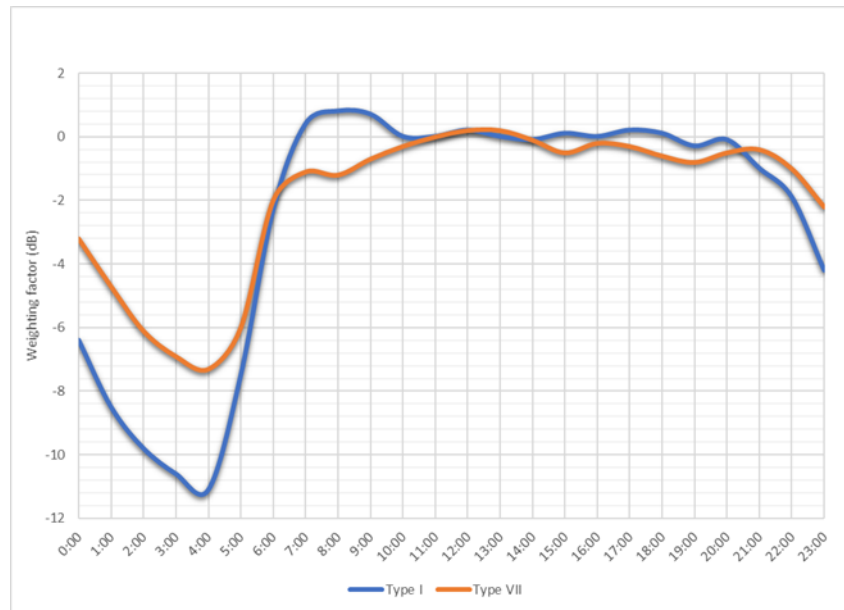


Figure 7. Time variation of Type I and Type VII streets.

Once the roads have been characterized, noise measurements are made at numerous points in the city with SADMAM vehicles, achieving a wide and well distributed spatial sampling thanks to the facility provided by these vehicles to measure anywhere in the city, which finally allows a better adjustment of the calculation model and, therefore, a more reliable and real noise map.

3.3. Leisure Noise

Nightlife is one of the sources of noise that causes most annoyance to citizens mainly due to the hours in which it develops which matches the resting time period.

For this reason, and in accordance with Law 37/2003, which establishes the obligation to declare the areas where the acoustic quality objectives are not fulfilled, even if each acoustic emitter observes the applicable limit values, as Special Acoustic Protection Areas (in Spanish, ZPAE), the City Council of Madrid has declared 4 ZPAE to date and has prepared its corresponding Specific Zonal Plans.

To date, the ZPAE declared by the Madrid City Council are:

- ZPAE Aurrerá (2010)
- ZPAE Distrito de Centro (2012)
- ZPAE Av. Brasil – AZCA (2014)
- ZPAE Gaztambide (2017)

At the time of preparing this document, the ZPAE of Centro 2018 is in the process of being approved, which reviews and updates the ZPAE of Centro that was approved in 2012.

The procedure that is carried out for the declaration of an area as ZPAE, comprises these three differentiated steps: the analysis of the area, the verification of compliance with the Acoustic Quality Objectives, and the elaboration of the Specific Zonal Plan.

In this process, the verification of compliance with the Acoustic Quality Objectives is fundamental, since it will be the factor that determines the declaration of the zone as ZPAE. For this, using the Mobile Network, the situation in the area is evaluated and the noise produced by the leisure activity is mapped in order to verify compliance with the Acoustic Quality Objectives. This verification is done through a

hybrid procedure, which combines the advantages of the evaluation by measurements with the advantages of the evaluation through simulations.

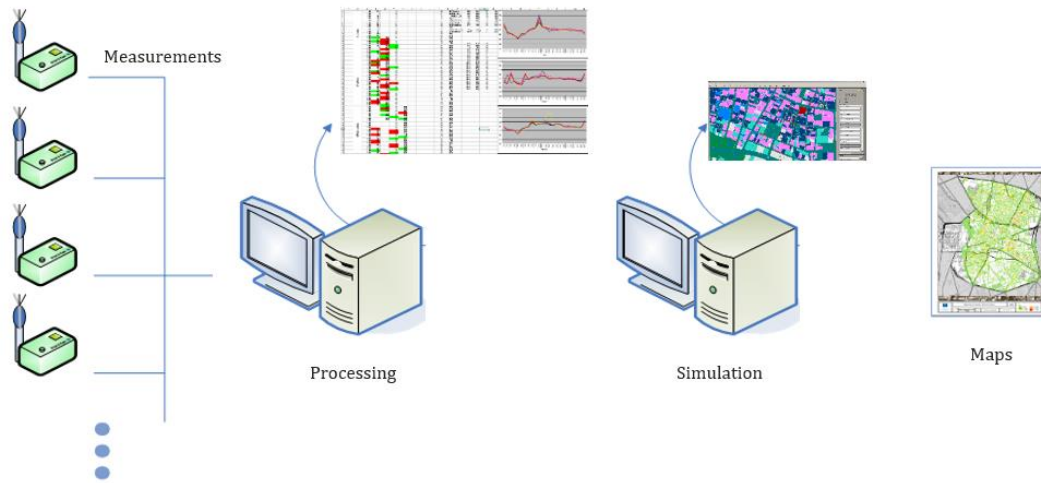


Figure 8. Hybrid procedure to declare an area as ZPAE.

The processing of all the information obtained using the Mobile Network allows knowing the values of the annual noise indicators, as well as determining the contribution to the noise sources existing in the analysed area.

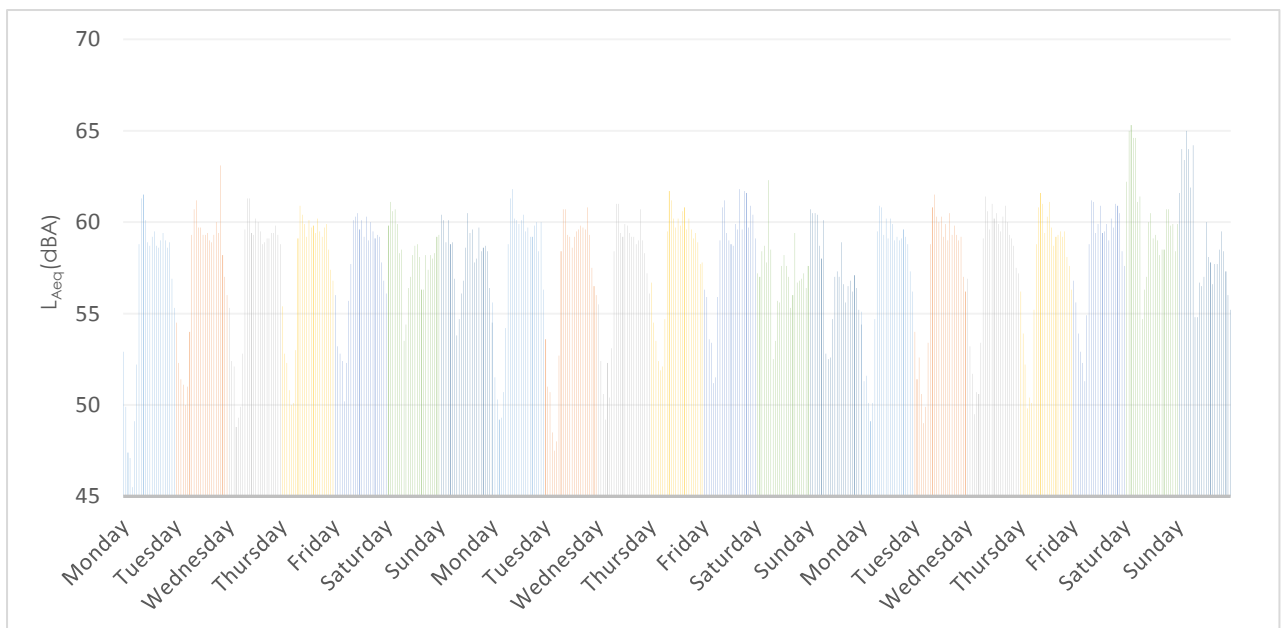


Figure 9. Time evolution of different days of the week.



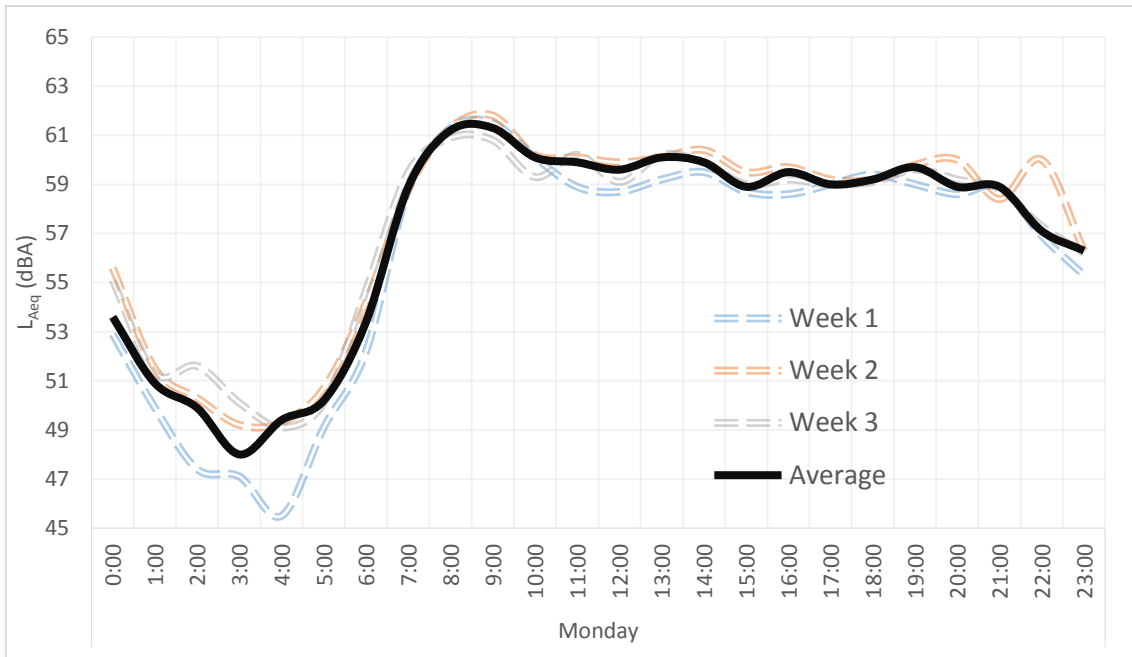


Figure 10. Average time evolution of different weeks at one measurement point.

The analysis of the measurements is essential when introducing the contribution of each of the sources in the calculation model, with which the cartography of leisure noise is finally obtained. For the review of the ZPAE of Centro, more than 80 measurements have been taken, for which approximately 60,000 hours of measurement have been recorded. All of this has allowed an exhaustive analysis to be carried out, with which to determine the predominant source in each of the measurement points, ensuring the reliability and representativeness of the calculations of the simulation model.

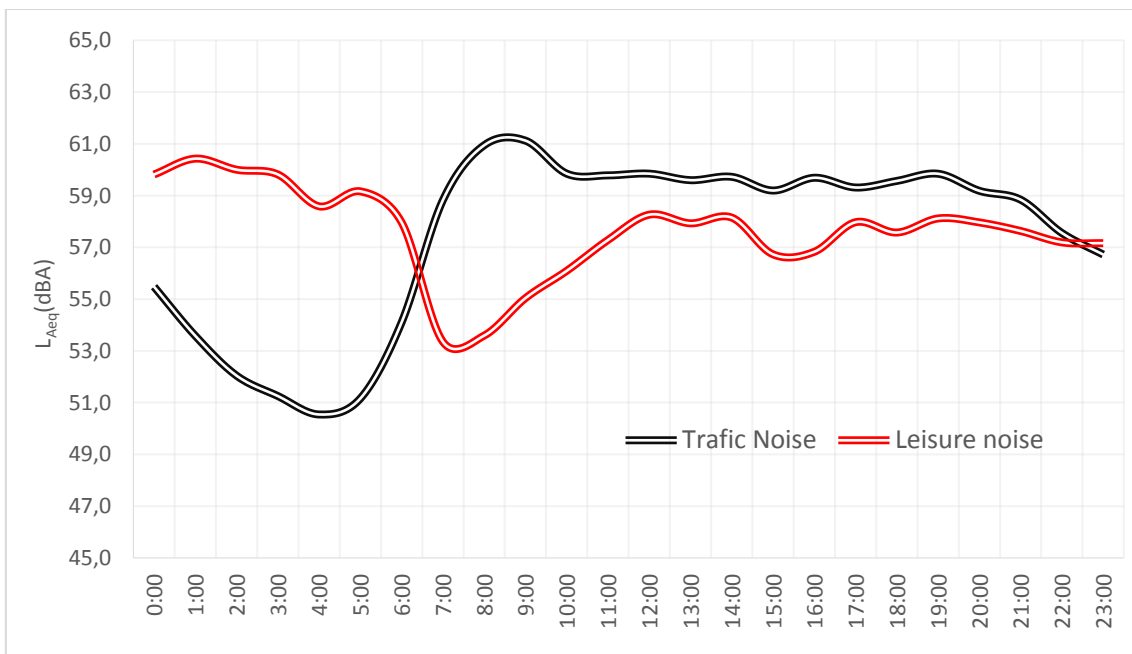


Figure 11. Time evolution of 2 different sources.

The previous graph shows the time evolution of the noise levels in two measurement points. It clearly shows the differentiated behaviour of the two existing sources of noise, especially during the night period that is most affected by leisure activity. The red line represents a measurement point located in an area with nightlife,

where the values reached during the night period are greater than the values recorded during the rest of the day. On the other hand, the black line represents a measurement located in an area with a traffic noise predominance, where the values at night are lower than the values registered during the day.

The results of the leisure noise cartography allow verifying the overcoming of the Acoustic Quality Objectives, in which case, the ZPAE is declared, and a Specific Zonal Plan is elaborated where, according to the degree of exceeding the Acoustic Quality Objectives, different actions will be taken to achieve the progressive improvement of the acoustic situation in the area.

4. CONCLUSIONS

Noise monitoring networks have become a fundamental tool in the management of noise in the urban environment, since they allow immediate access to the values of the noise indicators for citizens, they also represent the necessary structure on which to base strategic actions such as noise maps or action plans with more reliability and representativeness than those obtained exclusively through calculations.

The Madrid City Council experience is a sign of the multiple applications that noise monitoring offers. Starting from a correctly dimensioned and organized network, where devices are combined, some of them prevailing the measurement history, while others emphasize the importance of mobility, in order to ensure both spatial and temporal representation. This is completed by a team of technicians who process and analyse all the information obtained from the measurement equipment. All this, together with the precision of the instrumentation as guarantor of the reliability of the data, allows having a tool compliant with the normative obligations both European and national, as well as carrying out studies and supporting the actions and initiatives aimed at reducing noise pollution in a city in continuous development like Madrid.

5. ACKNOWLEDGEMENTS

We would like to thank the collaboration provided by the Madrid City Council, as well as the other EMS Brüel & Kjær technicians who work in the City Council.

6. REFERENCES

1. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.
2. Ley 37/2003, de 17 de noviembre, del Ruido.
3. Real Decreto 1513/2005, de 16 de diciembre, por el que se desarrolla la Ley 37/2003, de 17 de noviembre, del Ruido, en lo referente a la evaluación y gestión del ruido ambiental.
4. Real Decreto 1367/2007, de 19 de octubre, por el que se desarrolla la Ley 37/2003, de 17 de noviembre, del Ruido, en lo referente a zonificación acústica, objetivos de calidad y emisiones acústicas.
5. Ordenanza de 25 de febrero de 2011 de Protección contra la Contaminación Acústica y Térmica.
6. Chana Fernández L, Escobar Martínez G, García Martín J, Paniagua Ropero R, Ramírez Fernández P, Barbado Rodríguez E, Perera Melero P, “*Libro blanco de la contaminación acústica*”, edited by Ayuntamiento de Madrid, Madrid (2001).

7. EMS Brüel & Kjær. [Internet]. [Consulted on February 1, 2019]. Disponible en: <https://www.emsbk.com>
8. Ayuntamiento de Madrid. [Internet]. [Consulted on February 1, 2019]. Disponible en: <https://www.madrid.es>