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# GIS TOOL FOR LEISURE NOISE MANAGEMENT

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## ABSTRACT

In 2003 the Regional Government of Andalusia created a regulatory instrument for the evaluation and management of environmental noise, the so-called Acoustically Saturated Zones (or ZAS) which with some modifications is still in force. This instrument has been used mainly (but not exclusively) in residential areas affected by outdoor leisure noise and makes available to the administration a catalog of special noise mitigation measures. These measures must be implemented in such a way that they facilitate the reconciliation of the right of residents to adequate environmental quality and the need to support economic activity. That is why the objective of this work is to describe how a GIS tool has been designed to help city officials in the efficient management of noise. Thus, the heart of the tool is a geodatabase that handles information relevant to decision-making, such as noise levels, premises license data, records of complaints and inspections, population figures, etc. The city of Cadiz has been chosen as a case study since certain attractive urban places concentrate a dense offer of terraces, bars, restaurants, and other activities, turning these areas and their surroundings into poles of attraction for crowds.

**Keywords:** *Outdoor leisure noise, GIS for noise management, Acoustically Saturated Zones (ZAS), Outdoor terraces.*

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## 1. INTRODUCTION

Sources of noise and sounds from very different origins converge in the streets of our cities to create the acoustic environments in which we live. One of them is leisure noise. It seems quite proven that environmental noise can cause, statistically speaking, a wide range of adverse effects on health, depending on the source. This cause-effect is very well documented for traffic noise. Without wanting to expand on the list of studies, this type of noise is related to annoyance [1], sleep disturbance [2], and risk of hypertension in adults and heart disease [3]. The majority of studies that form the body of scientific evidence for the recommendations in these guidelines refer to noise exposure to noise-source-type based on noise levels estimations and measurements outdoors, usually at the most exposed façade of dwellings (according to the Environmental Noise Directive [4]). However, when describing the health consequences that leisure noise has on the population, the World Health Organization addresses the problem from the point of view of those people who are both, participants and harmed by noise [5]. In those cases, the recommendation is to reduce the yearly average doses from all leisure noise sources combined to 70 dB $L_{Aeq,24h}$. At the moment, there is not enough work in which self-reported sleep disorders have been analyzed using a questionnaire, and the significant high sleep disturbance curves due to noise from leisure activities at night have been extracted. Despite this lack, this work focuses on a population that suffers from the noise from outdoor leisure in their own homes.

In Spain, at the national level, there are no specific regulations on leisure noise, so there is a significant dispersion of the technical standards adopted at the regional and local levels. If a comparative analysis is made it can be verified that they have something in common. One is the definition. It does not matter if the official declaration is called Acoustically Saturated Zones (or ZAS, as in

Andalusia [6]) or equivalent, in all cases, the definition identifies the cause of the problem. That is, significant noise annoyance is produced by the addition of the premises and especially by the crowd of people who use those premises or are attracted by the area. Therefore, ZAS could be understood as a leisure noise hotspot, and, the municipality should pay attention to promoting coordinated actions in these areas to gradually counteract noise levels.
The objective of this paper is to describe how GIS tools can help city officials in the correct evaluation of the situation for better management of environmental noise in those ZAS.

## 2. CASE STUDY

### 2.1 City of Cadiz

Andalusia is the most populated region of Spain (more than 8.5 million inhabitants in 2022) located in the south of the country with a warm climate in summer, and mild winters which invite people to live on the street. Traditionally tourism has had a very high weight in the regional economy. The City of Cádiz is one of the provincial capitals of Andalusia (the province of the same name). It is a peninsula with kilometers of beaches that faces the Atlantic Ocean in the southwest of Andalusia and has 123,000 inhabitants. Taking advantage that Cadiz is considered the oldest city in West Europe since its foundation by Phoenicians dates back to 1100 BC the City Council is committed to a paradigm shift in the tourism model.

### 2.2 A chronological approach to leisure noise in Cadiz

The region of Andalusia has been acting against noise from leisure activities since the mid-1990s. It is important to identify which "factors of change" can support the solutions to leisure noise.

- Advances in scientific knowledge and technology.
- Keeping regulations for leisure noise protection up to date.
- Social changes and a policy determined to transform the city.

They are interrelated factors whose analysis makes it possible to explain both the successes and the failures in the management of leisure noise by the competent authorities in this region. Making a brief chronological review of the regulations-achievements, three periods can be distinguished in Cadiz and then explained in light of this interrelation, considering the delay between the release of the legislation and the desired effects begin to be felt.

#### *2.2.1 The 90s*

During this period the first regional environmental law was published where noise was considered an important environmental pollutant. The first leisure noise plan was included in the technical requirements for premises, forcing minimum acoustic insulation depending on the level of music expected inside. The opening and closing hours are regulated, as the mandatory use of the sound pressure level limiter (logger/limiter) in discos and pubs, where amplified music is common. It can be seen as in this period the problem of leisure noise is treated as people remain inside the premises. So the amplified music was the target. The most interesting achievements were the suppression of music outdoors (for example the open-air summer clubs have disappeared from urban areas) and effective control of airborne noise transmission to the street and structure-borne noise transmission to adjacent dwellings.

#### *2.2.2 Beginning of the 21st century.*

In Andalucia, the first regional noise decree was released in 2003 (and updated in 2012 [6]). The ZAS management tool was incorporated for the first time, in which outdoor noise from crowds was the focus. The catalog of mitigation measures applicable to ZAS problems includes:

- Total ban or time limitation of placing terraces in public venues.
- Restrictions for road traffic and parking.
- Imposing more restrictive noise limits than usual, requiring the holders of the activities to take complementary corrective measures.
- Suspension of the granting of new opening licenses, as well as their modification or extension, of those activities that may aggravate the noise problem (due to their schedule or type).
- More restrictive schedule than the regulation of Recreational Activities.
- Complemented by surveillance and actions of the local police.

In 2006, the prohibition of smoking inside the premises was incorporated through national law. During the same year, 2006, at the Andalusian level, regional Law 7/2006 prohibited the consumption of beverages in public urban spaces which can be classified as a countermeasure of the previous antitobacco law. Two types of crowds were

considered concerning anti-noise initiatives and mitigation measures included in ZAS official declaration in Cadiz.

(i) The first group is generated as a result of the premises and affects the streets where they are located. Several characteristics are common to this phenomenon but are not exclusive. For example, they occur at night and include people of all ages who prefer to drink alcohol outdoors in streets and squares lined with bars, pubs, and discos. Others go out to smoke, sometimes they take a break from the inner music level, or just to chat better. Tourists and locals integrate easily. In the downtown the narrow canyon-shaped streets make people speak very loudly due to the Lombard effect.

(ii) The second group is the most problematic and it is named (in a pejorative way) in Spanish: "botellon". These are groups of people (even thousands), usually very young and even minors, who come together to consume alcohol and have previously purchased it at low prices in supermarkets. For some, it is the warm-up before going to the discotheques and music pubs. For this reason, in Cadiz, they used to occupy parks and squares close to nightlife areas. This phenomenon is negative for residents, tourism, neighbors, and owners of nightlife establishments. It is a phenomenon that grew favored by social networks. Law 7/2006 prohibited the consumption of beverages on public roads. The Law itself allowed the installation of special areas outside urban centers where young people are allowed to drink avoiding the inconvenience to the neighbors of accessibility, noise, dirt (a clear example is shown in Fig. 1), and deterioration of street furniture, contrary to the first group analyzed where only the noise is the main inconvenience. The "botellon" problem ended between 2014 and 2016, through police work determined to fight this phenomenon by moving it to areas far from the urban area. The latest report from the Andalusian Ombudsman warns that the validity of the model is being questioned.

**Figure 1.** Plaza de Mina formed part of ZAS zones until 2020. The photo shows the dirt and pitiful appearance of the square after the "botellon" [7].

*2.2.3 Pre, during, and post-pandemic.*

From 2018 until today, the terraces flood the public spaces of the cities as a direct consequence of the pandemic. Currently, there are more than 400 terraces installed in the streets of Cádiz that can serve about 16,000 people. In 2020 a technical instruction was published as an addendum to decree 6/2012 for the evaluation of outdoor terraces [8] taking into account the noise objectives inside dwellings (bedrooms, and living rooms). This decree came out of the Covid19 situation that allowed the terraces to be expanded, but once the pandemic ended it is still in force. In some cases it has been allowed to extend the terraces towards sidewalks and car parks, in other cases they have been allowed to exist where there were none. The return to the situation before the pandemic is facing resistance. More and more municipalities promote people engagement and co-governance that allows stakeholder rethinking of how urban public space should be occupied in light of coexistence.

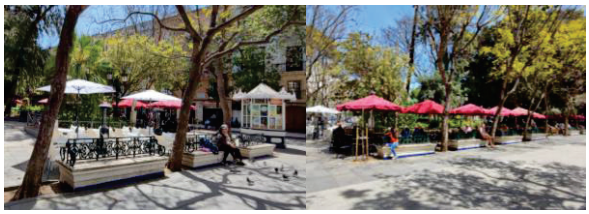

**Figure 2**. The current situation, is just the same place in the square shown in Fig. 1, with some of the terraces associated with restaurants.

From 2020 to the present there is no longer any area officially declared ZAS in Cadiz and that can be considered a success. The transformation that the central Plaza de Mina has undergone is noticeable (Fig. 2). The current problems related to leisure noise are also new for the municipality, but for the moment new statements from the ZAS are not being considered, for the following situations.

- The licenses for terraces allow their closing at 02:00 a.m. Complaints are preferably for the activities of the terrace staff to store the furniture from 02:00 to 02:30.
- Much in line with other cities, hotel penthouses try to exploit the lounge bar business, but it is very difficult for establishments to obtain licenses even with limited capacity (for example, only hotel clients).
- Pedestrianized areas, which have been completely closed to traffic (only traffic to parking lots is allowed) were presumably going to restore peace of mind. In reality, what has happened is exactly the opposite. The neighbors complain of a noise (crowd noise) that, due to its characteristics, is probably more annoying than traffic noise.

## 3. TOOL DESIGN

One of the advances in technology and science for a better evaluation and management of many kinds of environmental problems (noise included) is the Geographic Information System or GIS. Sometimes the help is as simple as having a geospatial data repository associated with Maps. In others, there is the possibility of creating tools through scripts that facilitate the work of municipality technicians. With all of them, the administration can efficiently deal with changes in leisure patterns in the city to try to give an effective response. Although the first version of QGIS appears in the year 2002, it was not until 2013 that version 2 appeared, when QGIS became a true OPEN SOURCE software alternative. This implied incorporating the functions of other commercial software and improving the user-friendly capabilities. This section explains the design requirements of the GIS repository that helped municipal technicians to manage their day-to-day work (especially with ZAS) precisely from 2013 until today. Using this schematic as a starting point below is presented a new tool designed in QGIS in its version 3.28, which serves for checking the terraces and bars on rooftops in a simple-to-use way.

### 3.1 GIS repository requirements for ZAS management

In 2013 the heart of the tool was based on QGIS 2.0 and it was composed of only two vector layer instances that compound the project: Public space (only considering the space available for pedestrians after discounting the space for vehicle traffic, street furniture, trees, etc.) and buildings (Fig. 3).

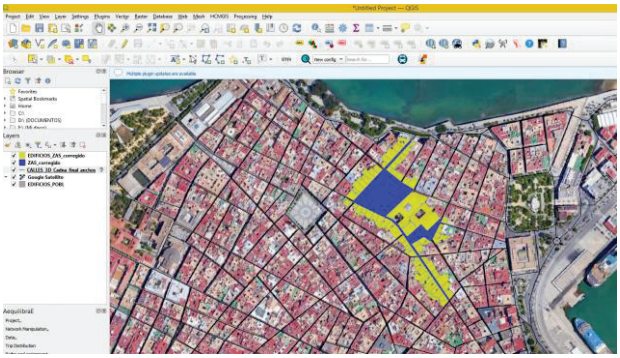

**Figure 3**. GIS maps that include Plaza de Mina and Plaza de San Francisco (in dark blue).

The building attributes geodatabase handles information (acoustic and non-acoustic) relevant to decision-making, such as:

- Uses of buildings.
- Addresses of residential buildings.
- The number of inhabitants per residential building.
- From the strategic noise map, The noise levels on the façade of buildings and the people exposed to noise levels can be broken down into building-by-building basis.
- A database of premises information. Name and type of premise (acoustically innocuous activity, bar without music, bar with music, disco, restaurant, etc.) accompanied by the license data of the premises, and photos (Fig. 4). Information about the capacity of the venues and the timetable.
- Record noise complaints and inspections. All complaints include a minimum of information made up of the date on which it was filed, the address of the complainant, and the place that caused the complaint. The date makes it possible to observe the evolution of the complaints about the situation before/after the introduction of a certain noise mitigation measure.

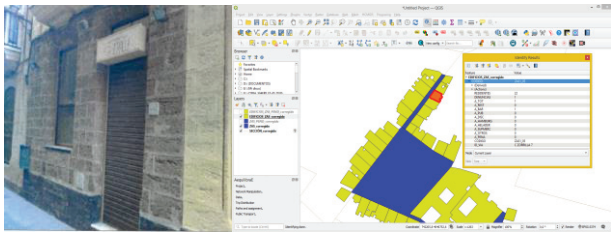

**Figure 4**. On the left, it is shown the photo of the bar that is now closed with several complaints. On the right, is shown the geodatabase of the building which at the time was affected by the bar and where the neighbors complained.

- Application for new licenses
- Results of noise measurement campaigns and noise predictions for the justification of the ZAS. Tab. 1 shows an example of the conclusions of the long-term measures on the facades (whenever possible on the first floor) that suffered from the noise problem. The measurements were carried out following the Andalusian noise decree of 2003 and refer to the same building that served as an example in Fig. 4.

**Table 1.** Some results of the noise measurement campaign.

| Plaza Mina and Calle Zorrilla (examples) - Lnight limit 55 dB | | | | |
|---|---|---|---|---|
| ID_VIA | Lnight_WE worst affection level during weekends | Lnight_LD minimum exposition level on labor days | Does it meet Criteria 1? Lnight>65 dB | Does it meet Criteria 2? Lnight_WE-Lnight_LD>10 dB |
| C ZORRILLA 10 | 68,3 | 55 | yes | yes |

Attributes linked to public space:

- Police reports regarding the activities and the surroundings. Disturbing noise in the streets due to crowds with the estimation of the number of people
- The surface of streets, squares, etc.

### 3.2 GIS tool design for terraces noise management

The post-pandemic terraces are growing and generating some noise problems, which should be analyzed. Not only terraces located in public spaces, but requests for licenses of ope-air bars with music and terraces located on hotel rooftops, are beginning to proliferate. Sound impact studies are requested from town planning every time a terrace is opened following technical instruction IT-8 [8]. Town planning departments do not usually have sound prediction software, they simply accept the conclusions of individual terrace studies. For this reason, an easy-to-use 3-D tool is proposed that aims to create lines of sight (LoS) that connect each noise source (S) with each noise receiver point (R) located on all floors of the residential building facades. At the moment it has been devised for a radius of 100 meters (projected on the XY plane). Under this same idea, more complex tools had already been developed previously, but in ArcGIS [9]. The information that is available in each of the receivers (R) is that of the noise and people exposed, but also that contained in the repository described in the previous section 3.1., which is that of every building. This information can be transferred, processed, and stored in the noise source (S), and vice versa. Every source of noise (In the case of terraces, it could be each of the tables when they are completely deployed) mainly contains the name of the premise to which the terrace belongs, the address, the total number of tables on the terrace, the maximum number of people, etc. Three methods are possible:

1 (M1). The simplest information in 3-D is the selection of S-R pairs that are visually connected within a maximum radius of 100 m.

2 (M2). At the same time, it is possible to use the lines of sight as a simple façade noise calculator. According to the IT-8 instruction, the noise power associated with the male human voice is defined according to the VDI 3770 [10], the noise power per speaker is $L_w$=73 dB. Using only divergence means that $LA_p$=73-20*$\log_{10}(d_{S,R})$-11 dB.. Very simple as the attenuation, reflection, and diffraction are excluded from the calculation. Finally, in each receiver, the sum of the noise levels provided by the sources within the radius of 100 meters is calculated. Setting all the S-R pairs, sharing the data between them, and processing the data to create new information, is a very complex process, but in turn, provides a very easy output for decision-makers to handle and interpret.

3 (M3). Using the noise maps at the façade of buildings as an input. Since the noise sources considered have the same noise power, the responsibility for the excess of the noise exposition (with respect to the noise limits) in each receiver (R) can be estimated directly. In case of excessive noise in the receiver, the sources that generate the excess noise are identified in included in the building geodatabase repository. Briefly, in the hypothetical case that all the distances S-R were equal, the relationship established between the noise level at a receiver point and the responsibility of each emission source is [9]:

$$L(R_{i,j}, S_n)_{equitable} = L(R_{i,j}) - 10 \cdot \log_{10}(N) \quad (1)$$

Where;
$L(R_{i,j}, S_n)$ is, the noise level contribution of the source point "n" on the receiver located at façade point "i" of building "j",
$L(R_{i,j},)$ is the noise that was estimated by the noise prediction software on the receiver located at façade point "i" of building "j",
N is the total number of noise sources within the search radius of 100 m that are visible from the receiver.

In general, the S-R distances will be different and then a weighting factor will have to be introduced in Eqn. (1), that will take into account the relation $d_{S,R}/d_{S,R,min}$ [9], being $d_{S,R.min}$ the minimum distance between a defined source and all receivers under its influence.

## 4. VALIDATION AND DISCUSSION

To show to what extent city officials can trust methods (M2) and (M3) a benchmark test is proposed. This has been carried out by comparing the results of a well-known noise software with the results of (M2) y (M3) for two different cases.

First of all, a façade noise map (considering all the floors of the residential buildings) has been carried out with CadnaA (Fig. 5) that includes the noise levels generated by the 8 tables (separated by 4 meters) that form a small simulated rectangular-shaped terrace. The chosen area is Plaza Mina and the simulated terrace is located in the same place that is presented in the photographs in Fig 2. The evening is the evaluation period (from 7:00 p.m. to 11:00 p.m.). Only one person speaks at a time at each table. During the evaluation period, 100% of the tables are occupied. The 30 residential buildings whose $L_e$ exceeds 30 dB are chosen for validation, which implies using 204 receivers linked to the facades of the buildings within a radius of 100 m.

The software CadnaA was used as a benchmark because takes into account (for noise estimations): attenuation, diffraction (vertical and horizontal), and (very important in this simulation) reflections (1 reflection was configured).

**Figure 5.** Results of the Façade noise map during the evening in CadnaA serve to propose the buildings that are going to be used in the validation of the alternative methods.

Case 1. The validation of the accuracy of alternative methods (M2) and (M3) was carried out in contrast with the noise levels caused by the 8 terrace tables chosen 1 by 1 on the 204 selected receivers. So, 8 façade noise maps were developed with CadnaA and with method (M2), but only one calculation process is necessary when using method (M3). The data involved in the validation is 1596 of the total of 1632 (no direct line of sight in 36 case). This figure matches the S-R different combinations. Fig. 6 shows the lines of sight S-R associated with the Source "terrace table n.2".

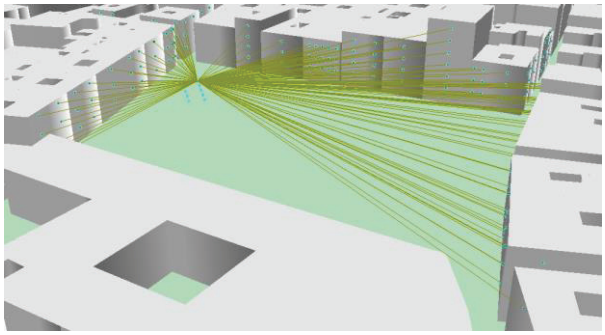

**Figure 6**. LoS of 1 source and 204 receivers.

Case 2. Also, the validation of the accuracy of alternative methods (M2) was carried out in contrast with the noise levels caused by 8 tables in the 204 receivers that were selected in CadnaA. So one façade noise map was developed with CadnaA and also with method (M2). Again 1596 LoS (and their distances) were used in the estimation of 204 noise data for the validation process. Fig. 7 shows the 8 lines of sight S-R of receiver number 148.

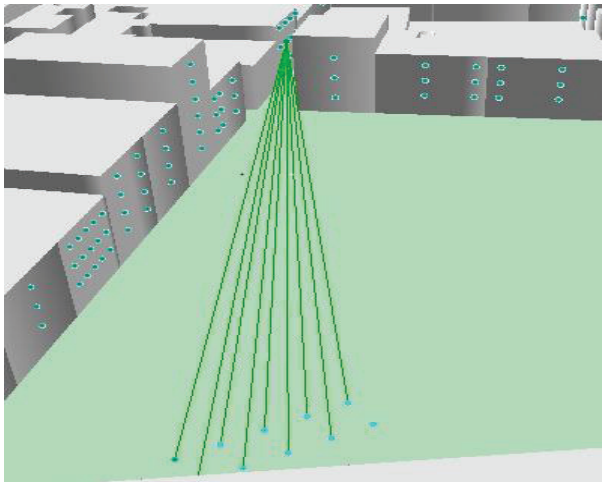

**Figure 7**. LoS of 8 sources and 1 receiver.

The results of the absolute error are listed in Tab. 2. The error is evaluated at the facade receivers. The relative error (mean, maximum, minimum, and standard deviation) was also calculated, but not reported.

**Table 2.** Absolute error (in dB) produced by both methods for the 2 scenarios under study.

| Case | Method | Absolute error | | | |
|---|---|---|---|---|---|
| | | <0.5 dB | 0.5 - 1 dB | 1 – 1.5 dB | 1.5 - 2 dB |
| 1 | (M2) | 94.3% | 3.9% | 1,8% | -- |
| 1 | (M3) | 91.9% | 5.1% | 2.6% | 0.4 % |
| 2 | (M2) | 86.3% | 7.8% | 4.4% | 1.5 % |

The largest errors are found in those receivers located on narrow streets as expected.

## 5. CONCLUSIONS

Following the case study of the city of Cadiz, it has been possible to interpret how noise problems have evolved in the city and in what context the GIS has helped to manage conflictive leisure areas under the official declaration of Acoustically Saturated Zones since 2013. Although relational geodatabases associated with maps are a very efficient management tool, lack analytical power. In this paper, 3 methods based on 3D-GIS have been proposed that could help city council technicians to analyze the influence of multiple terraces (in aggregated and disaggregated ways), in the vicinity of residential buildings. Although the terraces on rooftops of hotels have not been simulated, they can still be analyzed.

Lines of sight used in 3 methods (with very different levels of complexity and data entry requirements) provide flexibility to the technician who decides to make noise estimations, make searches looking for those responsible for excess noise in receivers, and make it easier to answer "what if..." questions, without the need for sound prediction software.

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