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# Evaluation of the $L_{Aeq}$ levels during the COVID-19 lockdown period using static wireless acoustic sensor levels in the city of Girona

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**Abstract:** The implementation of the lockdown measures in Spain due to the COVID-19 has had a deep impact on the soundscape especially in urban environments. One of the most clear effects is the decrease of the urban noise levels observed by means of noise mapping techniques using Wireless Acoustic Sensor Networks deployed in medium-size and big cities. This study pretends to reflect the variation of the noise levels in Girona, a 100.000 inhabitants city in the North-East of Catalonia (Spain). We have analyzed the $L_{Aeq}$ levels in eight different locations of the city from January to June 2020, including all the lockdown period, comparing with all the available noise monitoring data from the previous years (2019, 2018 and 2017 if available). The results show a considerable decrease of the noise levels in the street during all the hard lockdown. This analysis is part of the project "Sons al Balcó", which aims to draw the soundscape of Catalonia during the lockdown. Future work will be focused on finding dependencies between the equivalent levels measured in the sensors and the questionnaires and videos received from all the contributors in Girona.

**Keywords:** soundscape; COVID-19; equivalent level; Girona; urban noise level

## 1. Introduction

Environmental noise causes more than 48,000 new cases of ischemic heart disease and around 12,000 deaths in Europe per year, as World Health Organisation (WHO) states in their latest report [1]. Furthermore, it generates chronic annoyance to more than 22 million people and chronic sleep problems to more than 6.5 million [2]. Main focus of these works is on annoyance [3], and for this reason, the report presents the noise equivalent levels $L_{Aeq}$ values that should not be exceeded to protect citizens health.

WHO declared the COVID-19 pandemic an emergency on January 30th 2020 [4], and after that, the authorities of most European countries developed lockdown plans, based on restricting commercial flights, and decreasing the ground transportation [5] by means of closing schools and promoting the remote work, in order to try to avoid massive contagion. Spain promoted the same kind of measures to face the COVID-19 expansion, which were translated into stages with different level of confinement all along March, April and May 2020. This social, educational and industrial lockdown had a severe impact on the cities soundscape [6,7]. Most of the noise [8] associated with regular activities outdoors became almost nonexistent. Noise ground transportation, as traffic noise [9–12], railway noise, but also port noise [13], airport noise [14], industry noise [15] and leisure-related noise [16] were clearly reduced in the analyzed cities [17–19], and even in quiet residential areas [20].

There have been several initiatives to track the soundscape changes by means of the own perception and recordings from the citizens, as in the United Kingdom [21], Italy [22–24], New

York City [25] and even worldwide with the challenge of registering the exceptional soundscape conditions in all world cities [26]. In Catalonia, our project 'Sons al Balcó' [27] aims to study the effect of the lockdown due to the COVID-19 pandemic on the perception of the street noise. Despite the work presented in this paper is part of the project 'Sons al Balcó', in this paper we only focus on quantitative data, which comes from eight calibrated sensors deployed in the streets of Girona (Spain). We analyze only the values collected by the sensors during the first six months of 2020, as well as 2019, 2018 and 2017 when available to compare the street $L_{Aeq}$ levels among the four years and to evaluate the progression of the soundscape during the different stages of the confinement. Afterwards, this evaluation will be analyzed together with all the samples collected by 'Sons al Balcó' in the city of Girona, to conclude whether the objective measurements improve the perceptual evaluation given by citizens.

## 2. Location of the Sensors

The Wireless Acoustic Sensor Network (WASN) used to gather the data for this work is located in the city center of Girona [1], and it has eight sensors deployed in several points, detailed in the map in Figure 1. The sensors are located respectively: *1)* Rambla Xavier Cugat, *2)* Ramon Folch, *3)* Carrer Figuerola, *4)* Carrer Güell, *5)* Passeig d'Olot, *6)* Pujada de Sant Feliu, *7)* Plaça de Sant Feliu and *8)* Carrer Joan Maragall amb Bisbe Lorenzana.


**Figure 1.** Location of the eight sensors in the city center of Girona (OpenStreetMap, 03/01/2020)

The sensors have been designed by Urbiotica [2] and the signal processing corresponding to the equivalent levels evaluation has been coded by Keacoustics [3]. The sensors give a detail of $L_{Aeq}$ with a maximum temporal resolution of 1 minute. Therefore the signal processing developed for this study works with the raw data from the sensors working at $L_{Aeq,1min}$. The sensors collect data all day and night, and besides the technical maintenance stops and other communication issues that can occur at

1 http://visoracustic.girona.cat/VisorAcustic/ [last access 30/12/2020]
2 https://www.urbiotica.com/
3 https://www.keacoustics.com/en/home-en/

certain moments, the time-sequence of the data has been analyzed continuously all days of the week, and all hours of the day.

## 3. Stages of the 2020 Lockdown

As stated in [17], we can consider that the lockdown in Spain has had six stages, of different severity in terms of restrictions:

- Stage 1: 12/03/2020-13/03/2020 - School suspended and telework suggested.
- Stage 2: 14/03/2020-28/03/2020 - School, non-essential shops and any events closed, no walking outdoors, telework unless justified.
- Stage 3: 29/03/2020-12/04/2020 - School, non-essential shops and any events closed, no walking outdoors, telework unless justified. Non essential movement banned.
- Stage 4 (similar to Stage 2): 13/04/2020-26/04/2020 - School, non-essential shops and any events closed, no walking outdoors, telework unless justified.
- Stage 5: 27/04/2020-24/05/2020 - School and any events closed, telework unless justified. Walks allowed (major restrictions).
- Stage 6: 25/05/2020-07/06/2020 - School and any events closed, telework unless justified. Walks allowed (minor restrictions).

The different stages correspond also to changes in the soundscape of the cities involved in the policies. This weekly updates of the restrictions will help us to analyze the changes in the equivalent level $L_{Aeq}$ in Girona with the available data.

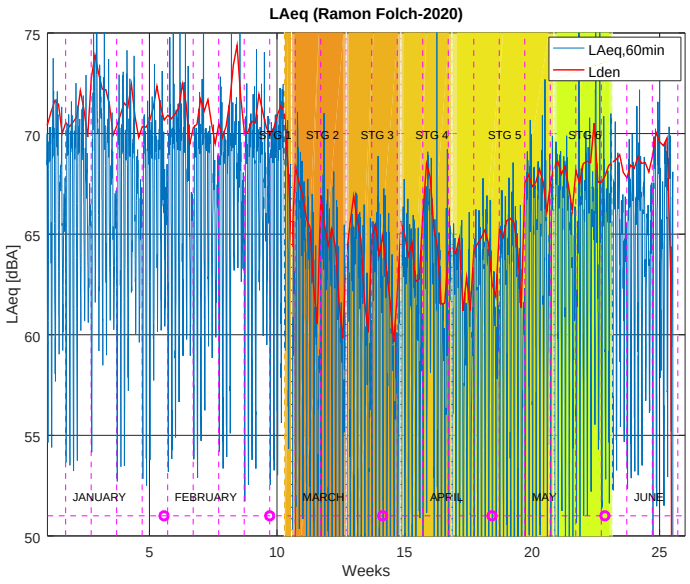


**Figure 2.** $L_{Aeq,60min}$ (in blue) and $L_{den}$ values (in red) for Ramon Folch sensor (#2) for Jan-Jun 2020.

## 4. Experiments and Results

This study has deeply evaluated the equivalent level values for the months from January to June 2020, and has also worked in analyzing the differences between the equivalent levels during the lockdown, and during the same weeks for the three previous years (2017-2018-2019).

### *4.1. $L_{Aeq}$ Values for Jan-June 2020*

The first conducted analysis corresponds to the evaluation of the $L_{Aeq,60min}$ and the $L_{den}$ [28] values for the 8 sensors in Girona, starting from the 2020 months from January until June, both included. Not all the sensors have their data collection complete, so, we chose here a representative example for illustrative purposes.

Figure 2 shows the $L_{Aeq,60mins}$ (in blue) and $L_{den}$ (in red) for the January-June months of 2020 for sensor #2. The Figure states that on March 13th the $L_{Aeq}$ values decrease drastically (just at the end of week 10 and the beginning of week 11), until week 22 -included- where the authors have stated that an event happened in the city and the levels increased for several consecutive days. The different stages of the lockdown are depicted in the figure, and it is remarkable that it is not until the final part of stage 5 that the equivalent level, during the week, starts to increase again. However, it does not yet reach the values previous to the lockdown, not even during week 23 and 24, mainly confinement-free. Another clear conclusion coming from Figure 2 is that the difference between the equivalent level during the weekend day and the weekday is larger during the confinement. The average dBA that the noise decreases during the weekend is around 1.03 dB in regular times, and more than 2.97 dB during the lockdown (week 11 to week 22 in 2020, for sensor #2). This analysis shown for sensor #2 has been evaluated for the eight sensors in Girona - assuming the available data - and several issues have arisen:

- There is data missing in sensors #1 Xavier Cugat and #3 Figuerola.
- There is wrong data in #8 Joan Maragall and #5 Passeig d'Olot.
- The difference between the $L_{den}$ during the weekend and during the week are wider during the lockdown, from 1 to 2 dB larger (depending on the sensor evaluated).
- Nevertheless, the curves do maintain the tend of lowering the values of $L_{Aeq}$ during the weekend, showing a pseudo-periodic result for all the 24 weeks analyzed.

### *4.2. Comparative analysis of 2020 $L_{Aeq,60min}$ values with former years measurements*

In this section we conduct the comparison of the average values of $L_{Aeq,60min}$ collected in the city during the same period of 2017, 2018 and 2019, against the values obtained in 2020, aggregating both weekday and weekend values. In Figure 3 we show the boxplots evaluating the differences between the historical series values collected and the values gathered in 2020 in sensor #2 (Ramon Folch) and sensor #4 (Güell). The upper plot shows the boxplots of the differences out of lockdown (weeks 1 to 10) and the lower plots show the results of the differences during stages 1 to 5 of the lockdown (weeks 11 to 19). The upper plots show both sensors collecting similar equivalent level data for the former years and for 2020, still out of lockdown. But the lower plots show clearly different results. In sensor #2 the differences during the lockdown are larger, especially at nighttime (24h-5h). Nevertheless, during the daytime, none of the median values for each hour are lower than 3 dB, with most of them around 5 dB. Sensor # 4 does not present so high values of difference during the night. However, during the day, and especially around 9-10 in the morning and 17-19 in the evening, the differences increase, probably due to the reduction of traffic noise, since these two periods of measurement correspond to schools and work rush hour.

## 5. Conclusions

The conclusions of this article underline that the equivalent levels of environmental noise fell substantially in the analyzed streets of Girona during the lockdown. Furthermore, it was observed that the difference in $L_{den}$ level in the city during the week and at the weekend presented higher values (around 1-2 dB higher) during the lockdown than in the normal period. The most relevant conclusion about the difference between the historical series of $L_{Aeq,60min}$ provided and the 2020 values gathered is that depending on the sensor evaluated, the decrease of $L_{Aeq,60min}$ is more relevant during the traffic rush hour in Girona, or during the first part of the night (23-04), but both of them can show relevant lower values around 5 dB and even 10 dB.

**Author Contributions:** RMAP has designed the experiments, written the paper and is the Principal Investigator of project 'Sons al Balcó'. PB has conducted most of the experiments over the raw data, and has reviewed the paper.

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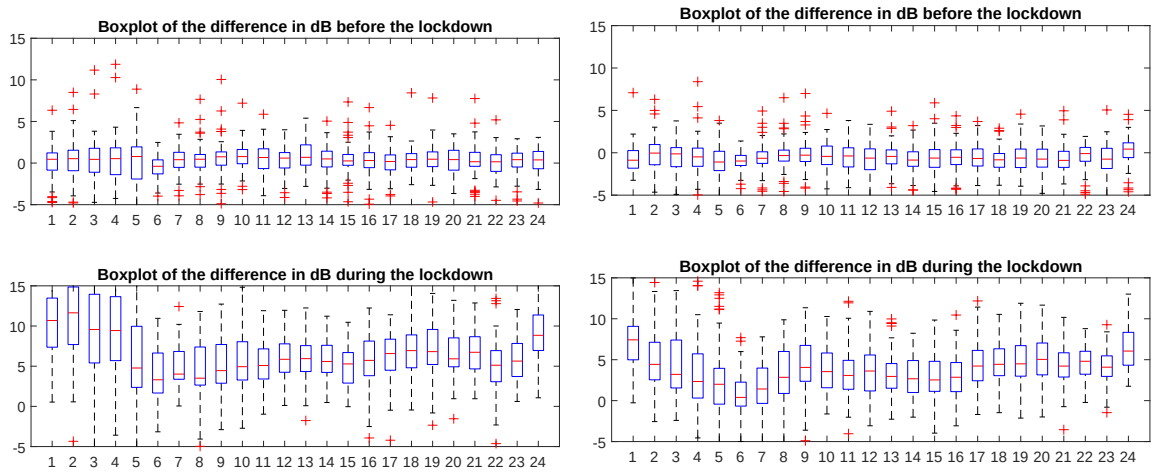


**Figure 3.** Boxplots of the differences of $L_{Aeq,60min}$ throughout 24 hours Ramon Folch sensor (#2) - left- and Guell sensor (#4) - right- for January-May period (out of lockdown - Stage 5 of lockdown), comparing the average values of 2017-2018-2019 against 2020 $L_{Aeq,60min}$ values.

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**Conflicts of Interest:** The authors declare no conflict of interest.

## Abbreviations

The following abbreviations are used in this manuscript:

| | |
|---|---|
| $L_{Aeq}$ | A-filtered Equivalent Level |
| WASN | Wireless Acoustic Sensor Network |
| WHO | World Health Organization |

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