Noise immission level reduction during the lockdown considering four main noise sources with the greatest impact on the population

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Abstract
This study analyses the noise immission levels evolution during COVID scenario in different urban environments due to the four main sources with the greatest impact on population: vehicle traffic in urban areas, industry, transport infrastructure and nightlife. This evaluation aims to find out in which scale the noise level decreased in the state of alarm declaration and how it evolved in the resumption of the new normal.
A wide noise sensor network was installed by AV Ingenieros with the initial objective of monitoring noise levels during the development of noise control and specific action plans. But during this monitoring the state of alarm was declared, so the sensors already installed were able to measure noise levels before, during and after the lockdown.
A parallelism can be seen between noise levels and some indicators that represent each environment. During the total lockdown, a greater reduction can be observed, and afterwards sound levels return to the usual levels in environments like the industrial, but levels have been lower in urban and nightlife environments, since the allowed capacity in activities or the mobility have also been lower than usual.

Keywords: noise exposure; noise continuous monitoring; noise reduction; noise and economic parameters.

1 Introduction

Noise pollution, according to the World Health Organization (WHO), is one of the environmental factors that causes more health problems. Some of the main noise sources that generate the most impact on the population are road traffic, industry and nightlife. These noise sources usually generate a seasonal acoustic impact, so the evaluation of sound immission levels must be done through long-term measurements or through continuous monitoring.
Continuous noise monitoring stations measure the equivalent continuous level with A frequency weighting during 24 hours / 7 days. This allows to have absolute control of the real acoustic impact and its evolution.
Since they are some of the main noise sources that affect the population, they usually cause the acoustic quality objectives to be exceeded and are usually subject to the implementation of mitigation measures to reduce the acoustic impact. In this case, it is essential to have a noise level monitoring system, before, during and after the implementation of the corrective measures, since it will be the indicator that determines the effectiveness of the developed measures.
This is the reason why AV Ingenieros has a wide network of continuous noise monitoring evaluating different noise sources that affect the population. This sensors network has made it possible to have noise data before, during and after the declaration of the alarm state and to be able to observe the evolution of noise levels in different environments.

This document has the objective of evaluating the sound levels in four environments affected by four of the noise sources with greatest impact on the population, analysing the noise records between January 1st, 2020 and March 31st, 2021.

2 Applicable regulations

2.1 International Standards

Internationally, the most widespread standard for noise evaluation is the *ISO 1996 Acoustics -- Description, measurement and assessment of environmental noise* by *Part 1:2016 Basic quantities and assessment procedures* and by *Part 2: 2017 Determination of sound pressure levels*. These standards have two main objectives, on the one hand to define the best methods for describing, measuring and evaluating the environmental noise of all types of sound sources and on the other hand, to harmonize this methodology internationally.

2.2 European Regulation

Directive 2002/49/EC of the European Parliament and of the Council of 25th June 2002 relating to the assessment and management of environmental noise, was created with the aim of reducing noise pollution caused by different types of noise emitters. This European directive establishes a set of objectives, including the creation of a common framework for all Member States for the assessment and management of environmental noise exposure.

2.3 National Regulation

The Spanish membership of the European Union led to the transposition of the basic provisions of the European Directive through *Ley 37/2003, de 17 de noviembre, del Ruido*, which has been developed with its subsequent decrees.
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, establishes a basic framework for the preparation of strategic noise maps with the aim of adding the concepts of nuisance and exposure to environmental noise proposed by *Directive 2002/49/EC* to the state legal framework.
Real Decreto 1367/2007, de 19 de octubre, por el que se desarrolla la Ley 37/2003, de 17 de noviembre, del ruido, en el Referente a zonificación acústica, Objetivos de calidad y Emisiones acústicas, has as its main objective to complete the development of the *Ley del Ruido*, defining the different noise indices, their application and establishing the acoustic quality objectives.

2.4 Autonomic Regulation

The reference regulation in Catalunya, related to the external noise immission, is *Decret 176/2009, de 10 de Novembre, pel qual s'aprova el Reglament de la Llei 16/2002 de protecció contra la contaminació acústica i se n'adapten els seus annexos*. The object of the decree is the *Llei 16/2002* development and the adaptation of its annexes in order to achieve the adequacy to those basic precepts of the state regulations that directly affect the catalan regulations.
The methodology for measuring and evaluating noise levels depends on the emitter focus. That is why *Decret 176/2009* incorporates a set of annexes for each of them. For example, *Annex 1* is developed for the evaluation of the noise immission level generated by infrastructures; *Annex 3* is developed for the evaluation of the external noise immission generated by activities; and Annex A is developed for the evaluation of acoustic quality objectives, which applies to all incident emitters.
These annexes also establish the limit values for noise immission and are different depending on the evaluated noise source and depending on the acoustic zoning of the evaluated receiver.

This acoustic zoning is regulated through the acoustic capacity maps that are of local competence and that are based on the predominant use of the land.

3 Instrumentation

The equipment that AV Engineers has used for noise measurements is a noise monitoring equipment (noise sensor) from the *Cesva* brand, *TA120* model. Figure 1 shows the image of one of the sound level sensors installed in a streetlight.

Figure 1 – View of one of the noise monitoring equipment installed in a streetlight.

The equipment used for noise assessment have the following extra items:

- Battery: The equipment has an internal battery that charges at night with the power from the streetlight.
- 3G modem: The equipment has an internal 3G data module, to transmit the recorded data from the equipment to the server for data management.

In this way, the temporal evolution of the level of sound immission registered by each of the equipment can be consulted in real time by *NoisePlatform* from *Cesva* and through AV Ingenieros' own server. The query parameter is the A-weighted equivalent sound immission level (L_{Aeq}) for each minute. Figure 2 shows, as an example, the visualization of the data recorded minute by minute. In addition, through *NoisePlatform* it is possible to check the noise levels recorded every hour or every day. Figure 3 shows an example of a weekly data display.

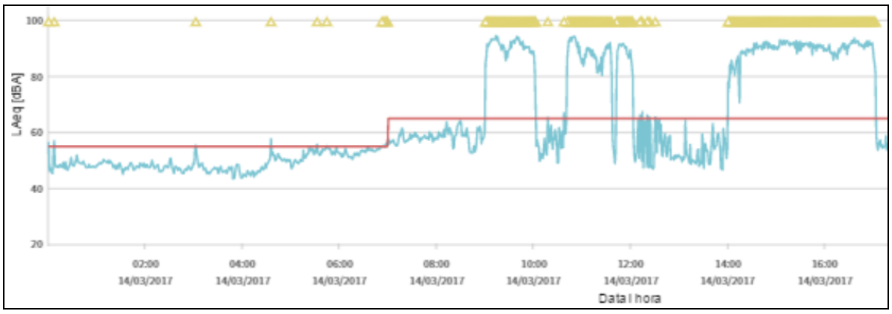

Figure 2 – Example of the temporal evolution of the sound immission level on a real-time platform.

dBA	06/03 Dl	07/03 Dt	08/03 Dc	09/03 Dj	10/03 Dv	11/03 Ds	12/03 Dg
00:00	49.6	55.3	50.2	50.4	49.4	50.4	46.6
01:00	49.3	43.9	51.8	50.4	50.4	50.8	45.7
02:00	48.3	45.9	49.1	51.4	51.4	49.6	45.2
03:00	49.4	46.1	50.7	50.0	51.8	50.5	46.3
04:00	51.2	47.1	48.6	51.0	52.9	50.9	45.4
05:00	55.2	51.4	50.2	52.4	55.7	51.2	48.0
06:00	57.0	55.2	48.9	54.8	57.2	52.6	50.4
07:00	57.3	57.3	55.3	58.7	57.9	56.0	52.3
08:00	56.9	56.8	56.2	57.9	56.0	52.8	51.3
09:00	54.6	81.7	81.7	82.2	82.1	48.6	47.5
10:00	70.9	81.9	82.5	83.4	81.8	49.7	68.8
11:00	71.6	82.4	82.0	82.9	80.7	50.3	65.5
12:00	53.8	81.6	83.3	81.6	81.5	51.9	60.0
13:00	51.9	71.9	74.1	54.1	72.3	70.1	48.6
14:00	69.1	80.3	78.8	82.4	78.5	50.6	49.6
15:00	69.4	83.5	81.6	84.1	83.8	50.6	68.0
16:00	67.0	84.9	83.8	84.1	82.3	50.4	51.2
17:00	53.3	86.6	83.3	85.0	82.9	75.9	53.2
18:00	55.3	58.5	57.5	66.9	69.8	51.8	54.0
19:00	52.8	53.9	55.1	52.9	54.8	48.7	50.1
20:00	52.6	52.7	49.6	52.6	52.2	50.1	47.1
21:00	49.6	50.9	50.5	51.3	54.0	49.6	48.4
22:00	49.8	49.1	49.4	51.0	52.3	47.9	47.8
23:00	51.2	51.0	50.4	50.9	50.9	48.3	49.4

Figure 3 – View the equivalent level of each hour for a week via the real-time platform.

As shown in the figure above, the display of the equivalent level every hour allows to know the sound level every hour throughout the day, to compare between weekdays and weekends levels or to correlate punctual events with recorded sound immission levels, allowing the detection of problematic events in terms of sound immission.

4 Boundary conditions

As already mentioned, this study considers the main noise sources with greatest impact on the population and analyses the evolution of noise immission levels before, during and after lockdown due to COVID-19 scenario.
Although all the evaluated points are located in an urban environment with exposed population, each of them has its own particularities. Then, the following subsections, make a brief description of each point and then some indicators are defined to allow the relation between the measured sound immission levels and economic parameters. Due to data confidentiality, the description that follows is made in a generic way without going into detail of its exact location.

4.1 Urban environment

The urban noise immission level is evaluated with a sonometric sensor located on a main avenue of a tourist town on the coast. This avenue consists of two traffic directions and one lane in each direction. The buildings in the area are for tourist use and on some of the ground floors there are shops. Just in front of the measurement point is the exit of a public car park, as well as a taxi station.
During the day it is a commercial area, while at night, nightlife predominates, so the evaluation of this point is made during the day level L_d.

4.2 Traffic impact

The noise level generated by a road infrastructure is assessed by an equipment installed in an urban environment affected by industrial use land, but with the existence of a main road that acts as a predominant focus and which masks completely the industrial activity noise. The buildings are multi-family GF+3 with commercial premises on the ground floor.

4.3 Industry

The measurement point used for the evaluation of the industrial environment is characterized by being an urban area affected by land for industrial use. This specific industrial activity is the main noise source that affects the residential buildings in the area, but they are also affected by a road infrastructure with considerable traffic intensity and by a railway infrastructure. In addition to these two noise sources, the measurement point is also affected by the traffic noise of the destination streets.
In relation to the operating conditions of the industry, it works from Monday at 6 a.m. to Saturday at 6 a.m., with a lower operating regime at night. In relation to the COVID scenario, the factory was stopped during the four first weeks of total confinement and then it has had a normal operation, but with closing for holidays in August and at Christmas.

4.4 Nightlife

Urban environment in a coastal tourist town with a high concentration of nightlife activities. Te street where the sensor is installed is pedestrian, with no traffic. Nightlife is one of the sectors that has been most affected by health restrictions. Music bars and discos were able to reopen their doors in June, although in mid-August they had to close again.

4.5 Indicators

To find out if there is any relationship between the acoustic quality of the environment and the economic and social situation, the evolution of the levels of sound immission is compared with the public data available on GDP, data on traffic intensity or economic data from private companies in the environment that may have influenced the noise results.

- Urban environment: GDP of the trade, transport and hospitality sector
- Traffic impact: No traffic intensity data are available, so noise levels are compared to GDP data
- Industry**:** GDP of the industrial sector and the economic data of the industry itself.
- Nightlife: GDP of the hospitality sector

5 Results

As already mentioned, the noise levels evaluation is carried out from January 1st, 2020 to March 31st, 2021. Although in each environment the evolution has been different, in all of them three scenarios can be observed: noise levels before the alarm status decree, noise levels during total lockdown and noise levels during return to the new normal. In this sense, the results are organized into the following two sections:

5.1 Noise reduction during lockdown

The state of alarm decree represented a radical change in the acoustic landscape in all environments, so this section evaluates the noise reduction between the previous sound levels and the sound levels during confinement. Table 1 shows, for each noise source, the noise level measured the days before de lockdown, set between March 2nd and March 8th and the noise level measured during the 4 weeks of total lockdown. Then below, the table details the noise reduction expressed in dBA and the reduction percentage considering the sound pressure indices.
As it can be seen in Table 1, the greatest noise reduction appears in nightlife, with a decrease of nearly 20 dBA, that supposes a 99% less noise. This is normal if it is observed that nightlife activities are practically the only noise source affecting the receivers, since the measurement point is in a pedestrian street with no road traffic.

The industrial environment also presents a significant noise reduction of 10 dBA, which represents a contribution of 90% lower. This is because the factory was stopped during the 4 weeks. If the reduction has not been less, it is due to the contribution of other noise sources unrelated to the activity, such as road traffic.
The most moderate decrease is observed in the environment affected by traffic noise from the main road, with a drop of 3.5 dBA representing 55% of its usual contribution.
Finally, the noise level L_d reduction in the urban environment is reduced by about 5 dBA, which represents a decrease of 70%.

Table 1 – Noise levels before and during lockdown and reduction in dBA and %.

	L_d - Urban environment	L_n - Traffic impact	L_n - Industry	L_n - Nightlife
Week before	69.3 dBA	60.6 dBA	62.7 dBA	73.3 dBA
4 weeks Lockdown	64.2 dBA	57.1 dBA	52.6 dBA	53.7 dBA
Reduction dBA	-5.2 dBA	-3.5 dBA	-10.1 dBA	-19.6 dBA
Reduction %	-69.5%	-55.5%	-90.2%	-98.9%

5.2 Noise reduction during 2020

The evaluation of the acoustic quality objectives must be carried out considering the period of one year. Thus, in this section, the noise levels of the initial acoustic situation are compared with the global levels for the entire year 2020, to know the impact of the drastic noise reduction in a specific period over the whole year period. For the evaluation of the noise levels for the rest of the year, it must be taken into account that in October another state of alarm was decreed to contain the spread of COVID infections, which especially affects noise levels at night and during the weekend.
Next, Figure 4 to Figure 7 show the evolution of the daily levels throughout the entire period under study, while Table 2 shows the averaged levels and the reduction it entails with respect to the acoustic situation prior to the COVID scenario, characterized by records obtained between January 1st and March 8th, 2020.

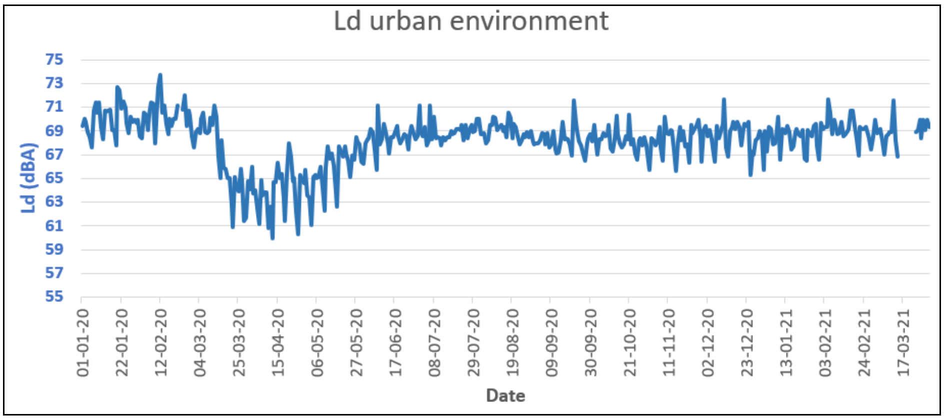

Figure 4 – L_d noise level evolution in urban environment.

In urban surroundings, it can be clearly observed how the noise level decreases on the first weeks of confinement and how it progressively recovers till remain stable as of June. What can be observed as of October are lower peaks that correspond to weekend days, in which the perimeter confinement and the closure of trade were decreed, with the exception of essential establishments.

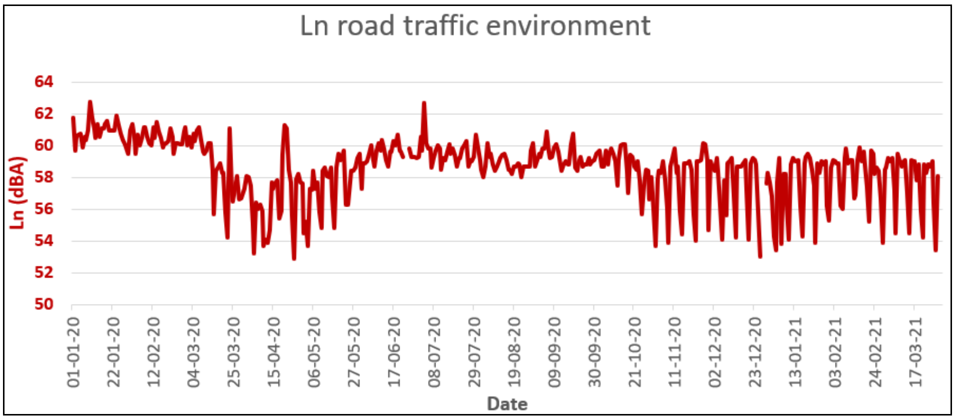

Figure 5 –L_n noise level in road traffic environment.

As observed in urban environment, a drastic decrease of noise level is observed during the total confinement and a progressive recovery is observed responding to de-escalation phases towards the new normal. From the end of October there are also lower peaks that correspond to the perimeter closure and the closing of commercial activities during the weekend.

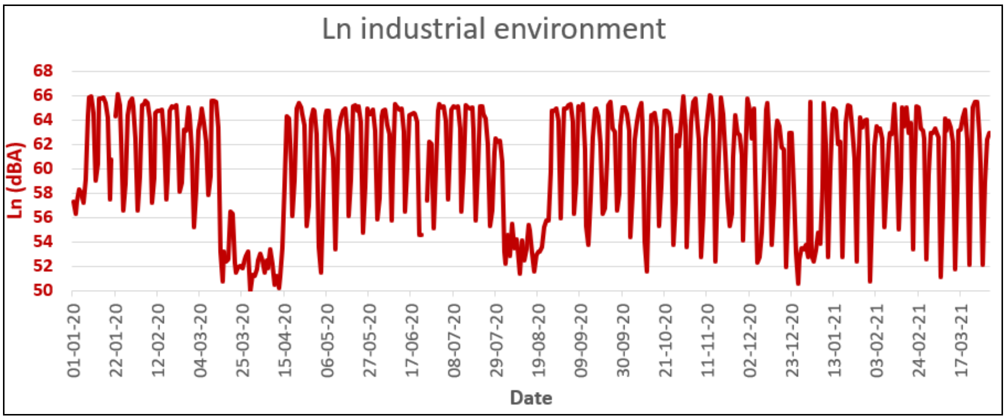

Figure 6 –L_n noise level in industrial environment.

The noise level measured in the industrial environment only shows variations during the days in which the factory has been shut down, corresponding to the temporary closure during total confinement and the closure corresponding to vacation days, as observed in August and in Christmas. The rest of the days the industry has operated under normal conditions.

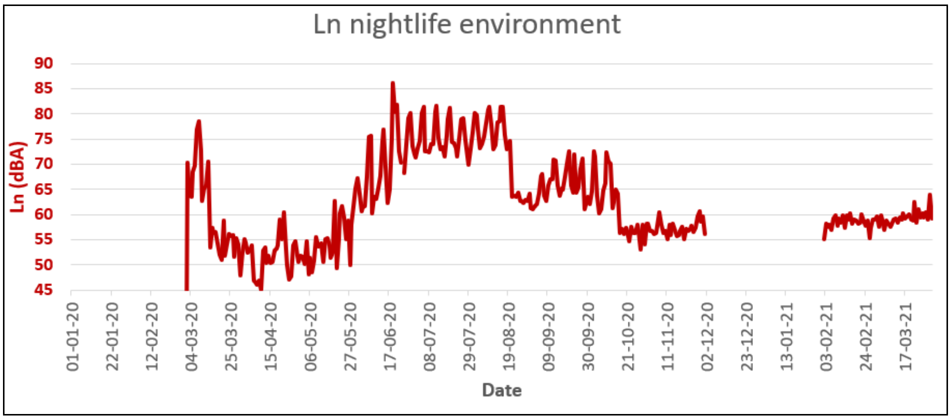

Figure 7 –L_n noise level in nightlife environment.

The available data corresponding to the sound sensor installed in the nightlife environment shows an evolution of the noise level in several phases. First, it appears the noise levels prior to the declaration of the alarm state and later the drastic fall due to the closure of all activities. Starting in mid-May, the noise level increases progressively until July, when normal noise levels are recovered and remain until mid-August, when the closure of nightlife activities is again decreed. From this date until mid-October another phase with average noise levels is observed, but as of mid-October, the perimeter closure and the curfew mean that noise levels remain lower.

Table 2 – Noise levels before lockdown, averaged 2020 levels and reduction in dBA and %.

	L_d - Urban environment	L_n - Traffic impact	L_n - Industry	L_n - Nightlife
2 months before	70.3 dBA	60.8 dBA	63.4 dBA	72.1 dBA
2020 average	68.5 dBA	59.1 dBA	62.2 dBA	70.8 dBA
Reduction dBA	-1.8 dBA	-1.6 dBA	-1.2 dBA	-1.3 dBA
Reduction %	-34.5%	-31.3%	-23.3%	-25.6%

As it can be seen in the Table 2 the greatest noise reduction is observed in the urban environment and in the environment affected by traffic noise. Although the reduction observed only during the days of total lockdown was not the most pronounced of the 4 noise sources (see Table 1), it has been a noise reduction sustained throughout the whole year due to reduced mobility.
The acoustic quality objectives in the other two environments are affected by a predominant noise source, so the absence of this source totally conditions the results. This means that on days of total closure, the levels are clearly lower than the usual noise levels, but once the activity is resumed, the noise levels return to the usual situation. In the energy averaged noise level carried out to obtain this objective index of acoustic quality, the high noise levels outweigh the lower noise levels, which means that the noise level averaged throughout the whole year does not look so affected.

5.3 Indicators comparative

Below, Figure 8 to Figure 11 show the relationship between the sound immission levels of the 4 environments with the indicators set in each case as described in the section 4.5.

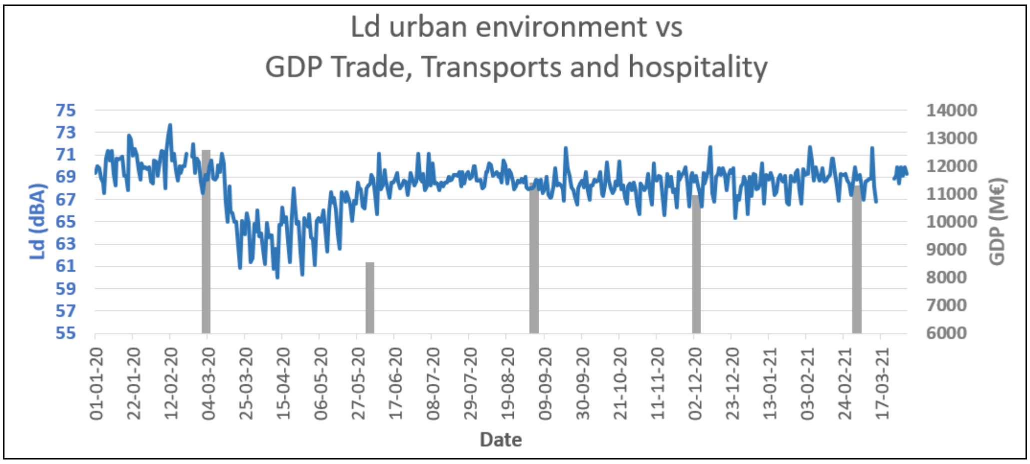

Figure 8 – Comparison between the noise level L_d in urban environment and GDP in trade, transport and hospitality sector.

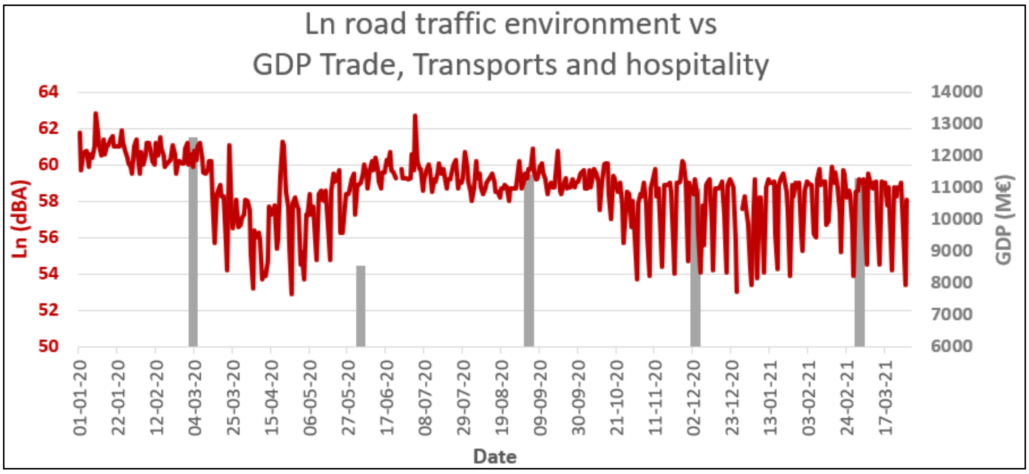

Figure 9 – Comparison between the noise level L_n in road traffic environment and GDP in trade, transport and hospitality sector.

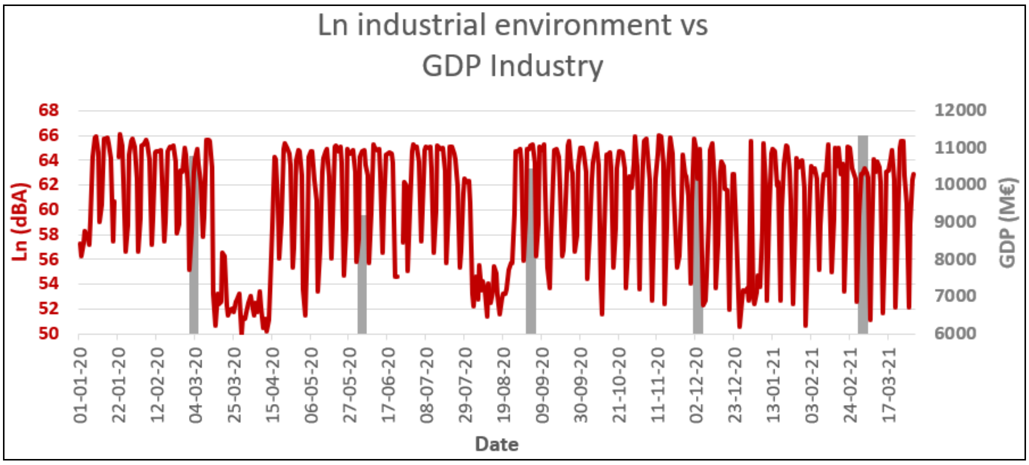

Figure 10 – Comparison between the noise level L_n in industrial environment and GDP in industrial sector.

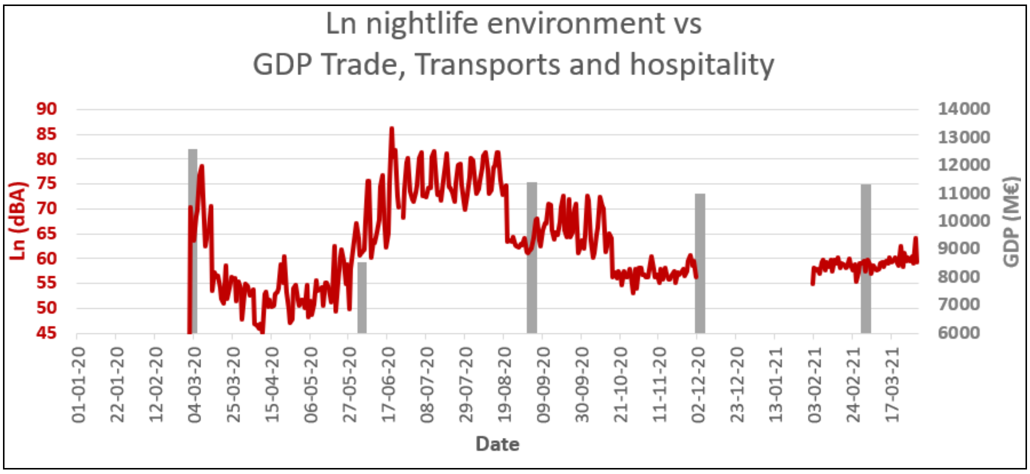

Figure 11 – Comparison between the noise level L_n in nightlife environment and GDP in trade, transport and hospitality sector.

As can be seen in the previous figures, the noise level is an index that immediately reflects the different phases conditioned by the different scenarios of the pandemic, while the economic indices are collected a posteriori.
In relation to the GDP of the commercial and transport sector, the second quarter of 2020 shows a reduction of 32% compared to the previous quarter. This decrease follows a similar proportion to the decrease observed in the noise level due to road traffic, which stands at 36% in the same period. Even so, the same does not happen in the evaluated urban environment, since the decrease in urban noise in the second quarter of 2020 is 47% compared to the previous quarter.
In relation to the industrial environment, the representation through quarterly results is not useful, since the local confinement lasted 4 weeks, 2 of them are recorded in the first quarter and the other 2, in the second quarter. In this case, in order to know if there is a parallelism between the acoustic and the economic situation, the specific economic indices of the industry that affect the measurement point are consulted. In this sense, the data available correspond to the annual averages, being able to observe in 2020 a reduction in turnover of 16% compared to 2019. In this case the reduction in noise indices is higher, since in global terms, the noise level for the entire year 2020 is 23% below the usual acoustic situation.
Finally, regarding to nightlife, as it is such a specific sector, noise levels cannot be compared with such a global economic index, so there is no clear parallelism. Even so, if the data is analysed in global terms observing the entire year, the reduction in the economic index in 2020 is 25% compared to 2019, while the reduction in the noise level in the same period is 26%.

6 Conclusions

The declaration of the state of alarm and the different restrictions, in relation to commercial closures, local confinements and curfews have totally modified the acoustic scenario throughout 2020.
The greatest noise reduction observed in the four evaluated environments (urban environment, road traffic, industrial and nightlife) undoubtedly corresponds to the first four weeks of confinement, with a reduction of 70% in the daily level L_d of urban environment, a reduction 55% in the night level L_n generated by road traffic, or a reduction of 90% and 99% of the night level L_n due to the total closure of the industrial plant and nightlife, respectively.
From the de-escalation phases towards the new normal, it is observed how sound levels recover. In those environments conditioned by a very predominant source of noise, such as industrial or nightlife, the levels are equal to the previous acoustic situation, but the sound levels remain a little lower than usual in urban environments, since that mobility has also been reduced.
Noise levels evolve in a similar way to the evolution of economic indices, since the GDP of the commercial and transport sector in 2020 is 25% lower than in 2019, while the decrease in noise levels in 2020 compared to the acoustic situation prior to the pandemic is 34% in the urban environment, 31% in the environment affected by traffic noise and 26% in the nightlife environment.