Research Article

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Noise at the time of COVID 19: The impact in some areas in Rome and Milan, Italy

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Abstract: The COVID-19 pandemic was confirmed in Italy at the end of January 2020, when the first positive cases for the virus were identified. At the beginning of March, the virus had spread to all Italian regions and on 10 March 2020 the lockdown phase began, limiting the movement of people and prohibiting almost all commercial activities, businesses and non-essential industries. As a result, millions of people were forced to stay at home, causing a drastic drop in traffic volume, which significantly changed the acoustic environment and air quality of cities. On 4 May 2020, the lockdown was partially lifted and activities were progressively reopened. Therefore, traffic gradually started to increase and, consequently, the noise emitted by motor vehicles. This behaviour was confirmed by the data collected by the DYNAMAP system, an automatic platform developed within the LIFE DYNAMAP project, providing real time traffic noise maps in terms of sound pressure levels and impacts at receivers (people and dwellings exposed to noise level bands). In this paper traffic and non-traffic-related noise events in the cities of Rome and Milan from March to May 2020 are analysed and compared to the corresponding values in 2019 to evaluate the effects of the lockdown period.

Keywords: effects of the pandemic on noise; change in traffic noise during Covid-19; urban ad suburban noise during pandemic

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1 Introduction

The COVID-19 pandemic was at first identified in Wuhan, China, in December 2019 and the World Health Organization declared the outbreak a public health emergency of international concern on 30 January 2020 [1]. Authorities worldwide responded by implementing travel restrictions, lockdowns, workplace hazard controls and facility closures, as an effective and easy to implement measures to avoid the spreading of the contagious [2].

In Italy the COVID-19 pandemic was confirmed on 31 January 2020, when two Chinese tourists in Rome tested positive for the virus. A cluster of cases was later detected, starting with 16 confirmed cases in Lombardy on 21 February and 60 additional cases, including the first deaths, on 22 February. By the beginning of March, the virus had spread to all regions of Italy and on 10 March 2020 Italy was locked-down, prohibiting nearly all non-essential commercial and industrial activities, including the movement of people.

As part of the lockdown measures, millions of people were forced to stay at home, resulting in a drastic fall of traffic volume, that significantly changed the soundscape and air quality of cities [3]. Suddenly people rediscovered natural sounds and the peace of an unchaotic life, as well as cleaner air.

On 4 May 2020, the lockdown was partially revoked and gradually activities came back to life. These included travelling to return to permanent place of residence, working, visiting relatives who live in the same region, going on long walks, running or biking for exercise. On 18 May 2020, also museums, libraries and retail stores were reopened and on 25 May 2020 the lockdown was released for hairdressers, barbers and beauticians, bars, restaurants, ice cream shops and patisseries. Since the first of June 2020, all activities have been reopened, with the only exception of schools that were planned to keep staying closed until the next school year (September 2020). However, many workers, especially those employed in public administration, were solicited to keep working at home.

Despite Italian government prescriptions, traffic gradually began to grow and consequently the noise emitted by motor vehicles. In order to study the traffic variation and the environmental noise dynamics within this period, a huge number of traffic and noise data have been collected and analysed in a timeframe ranging from January to May 2020 and compared to the values detected in the same period the year before (2019). Noise data were gathered from the DYNAMAP System [4, 5], an automatic platform developed under the LIFE DYNAMAP project in the cities of Milan and Rome, providing updated noise maps in real time, including the estimate of the number of people and dwellings exposed to noise levels.

In the following paragraphs a short description of the DYNAMAP system is given, followed by detailed information on traffic, noise and impacts before and during the lockdown in the cities of Milan and Rome, respectively.

A comprehensive data analysis is finally provided to assess the effects engendered by the lockdown measures.

2 The DYNAMAP system

DYNAMAP is an automatic noise mapping system, able to detect and represent in real time the acoustic climate of road infrastructures (Figure 1) [6]. The system is mainly composed of:

- a monitoring network installed along the road infrastructures [7];
- an open-source WEB-GIS platform able to process and report data, update the noise maps and communicate with the public.

The monitoring network is made of low-cost noise monitoring devices, developed under the LIFE DYNAMAP project. The monitoring devices detect the noise levels, clean the noise signal from anomalous noise events (*i.e.*, those acoustic events unrelated to road traffic noise, like the passage of trains or aircrafts, sirens, anthropic noise, etc.) and send data to a central unit for further processing and real-time updating of the maps.

The signals are cleaned by an algorithm known as ANED (Anomalous Noise Events Detection) [8], directly embedded in the monitoring devices, capable of identifying and eliminating anomalous noise events (ANEs) caused by the presence of secondary noise sources (railways, airports, street works, people, etc.), in order to provide a more accurate assessment of the acoustic impact of road infrastructures. The algorithm is implemented as a two-class classifier that discerns input acoustic data as ANE or Road Traffic Noise (RTN) every second. The algorithm was trained (before the lockdown) using two acoustic datasets collected through the deployed acoustic sensor networks, totalling more than 150h of labelled data each one, with 1.8% and 8.6% of ANEs in the suburban and in the urban acoustic environment, respectively (see [9] and [10] for further details).

Data captured by the monitoring devices are managed and published by a software application, named NOISEMOTE (http//www.noisemote.com/). This application has three main layers that allow to display real-time data, historic data and statistical evaluations in a time frame defined by the user.

The update of the noise maps is carried out by a WEB-GIS platform, capable of generating dynamic noise maps and a series of statistical information compliant with the requirement of the European Directive 2002/49/EC on environmental noise and of the current Italian regulations.

The DYNAMAP system has been implemented in two pilot areas with different territorial and environmental characteristics: an agglomeration (District 9, Milan) and a major road (A90 motorway, Rome).

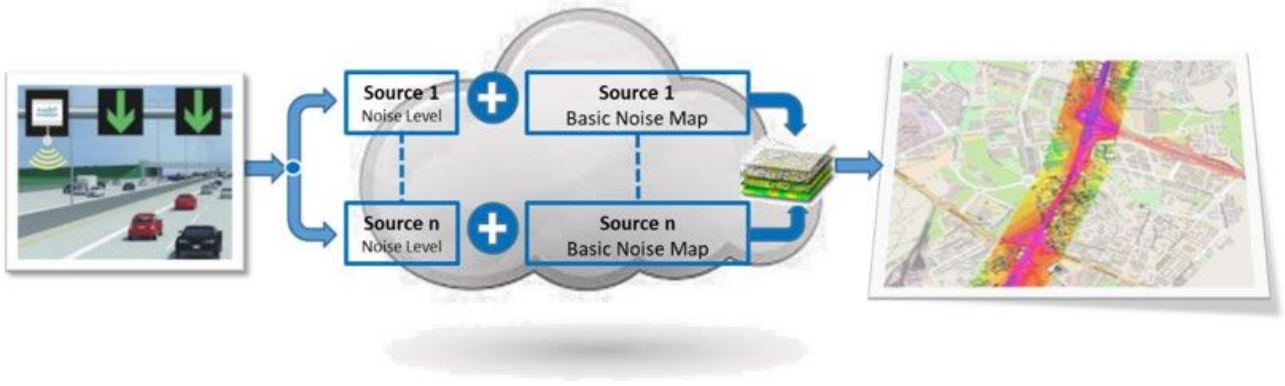


Figure 1: Schematic representation of the DYNAMAP system

Figure 2: The pilot area of Milan: a) a view of the area; b) an excerpt of dynamic noise map provided by the Dynamap WEB-GIS platform

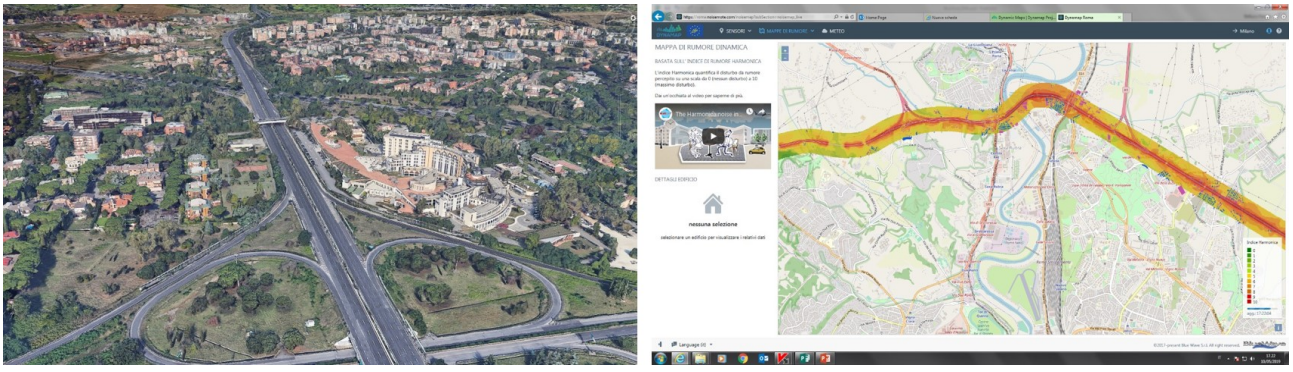


Figure 3: The pilot area of Rome: a) a view of the area; b) a portion of a noise map provided by the Dynamap WEB-GIS platform

The pilot area of Milan is located in the northern part of the city, in a strongly built-up area with high population density and a wide-spread road network (Figure 2). Due to the high number of roads in the area, a statistical approach was used to size the monitoring network. Therefore, roads having similar traffic features, and consequently similar noise trends, were grouped together by means of a cluster analysis [11]. Six groups were identified and for each group a suitable subset of road segments was selected for the installation of the monitoring devices. The noise detected by these devices represents the contribution from all roads in the same group. This contribution is used to update the noise maps. The update is carried out with a frequency depending on the time of day: 5 minutes from 07:00 to 21:00; 15 minutes from 21:00 to 01:00; 60 minutes at night from 01:00 to 07:00 [12].

The pilot area of Rome is located along the A90 Motorway (Rome's Grande Raccordo Anulare), the outer ring road that encircles the city, with many intersections with the main urban roads (Figure 3) [13]. In this case, the system configuration was based on a deterministic approach and the road was divided into 19 road stretches with similar traffic characteristics. Each segment was equipped with a sensor positioned on the top of a portal present in the mapping area. The noise levels detected by these devices are used to update the noise maps with a 30-second time frequency at daytime, from 06:00 to 22:00. At night, when the traffic is lighter and less continuous, the noise maps are updated every 5 minutes.

3 Traffic noise and impacts on receivers in the city of Milan

In Italy, the lockdown phase started on March, 10th 2020 and ended on May, 3rd 2020. That period was followed by a four-week second phase, during which restrictions were gradually removed.

In this paragraph the effects of the lockdown and the following transition phase are analysed and compared to those related to the same period in 2019.

In the pilot area of Milan (District 9), located in the Northern side of the city, the data related to environmental noise levels were retrieved from 24 monitoring devices installed along selected streets representative of the afore-

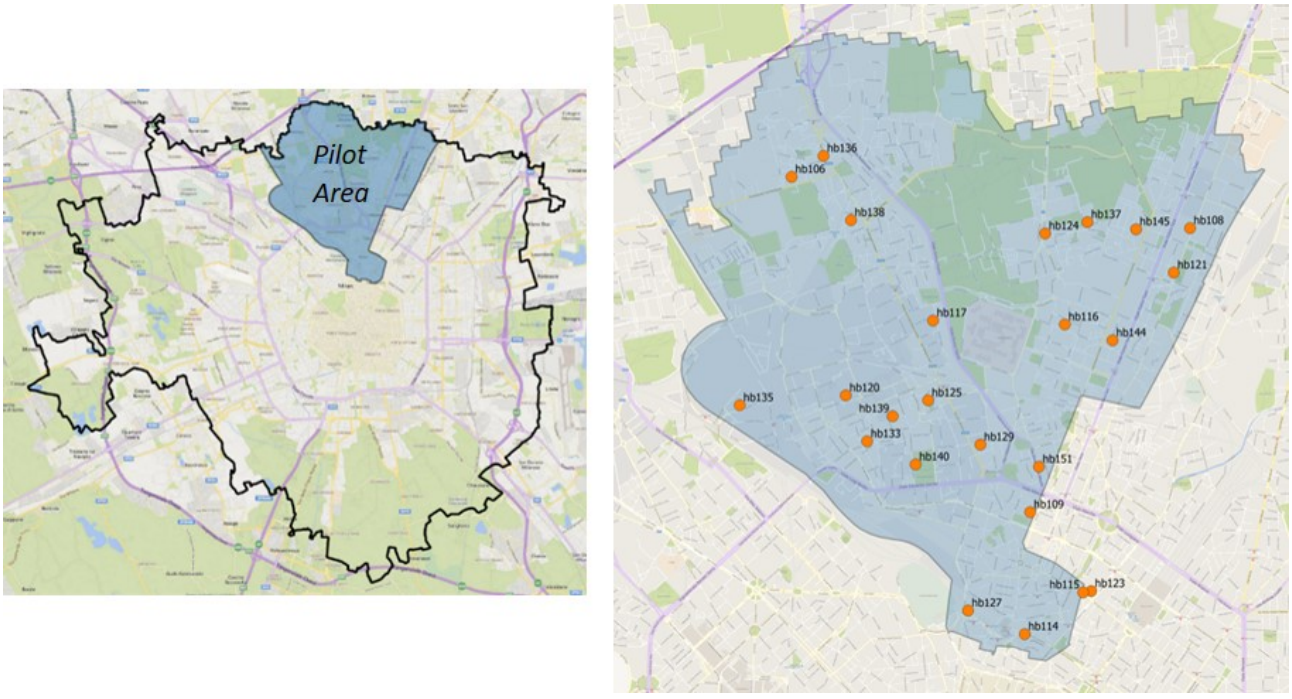


Figure 4: Location of the urban pilot area inside Milan municipality (on the left). Position of the 24 noise monitoring terminals in the pilot area (on the right)

mentioned six road clusters. Figure 4 shows the position of the 24 sensors located in the pilot area.

3.1 Traffic noise

During the lockdown period a drastic reduction of traffic volume was observed. This gave rise to a corresponding reduction of noise levels, as detected by the DYNAMAP monitoring devices, that pointed out a decreasing trend in every roads cluster.

In Figure 6 the noise trends related to the European indicators L_{den} and L_{night} from January to June 2019-2020 are compared. In order to show a general trend of urban traffic noise levels, the data provided by the 24 sensors have been averaged together on a weekly basis.

The graphs of Figure 5 clearly show the abrupt reduction of noise levels in the lockdown period (starting from week 10 until week 18) and the slow return to normal in the following weeks, from May to June 2020. Night levels have a trend as similar as L_{den} levels. The anomalous peak in week 23, 2020 (just after the end of the full lockdown), is due to some extraordinary meteorological events, which have not been adequately detected by ANED because of their persistence for several days.

By analyzing the single noise levels detected by the 24 monitoring devices, it is possible to obtain the maximum difference between 2019 and 2020 average weekly values for each sensor during the lockdown period. In Table 1 some statistical features of this dataset are reported for the indicators L_{den} and L_{night}.

As it can be seen the average of the maximum difference during the lockdown period, compared to 2019, is 7,3 dB(A) for L_{den} and 7,6 dB(A) for L_{night}, with peak of 11,7 and 12,8 dB(A) respectively. The maximum difference has been detected by the sensors located in the central part of the pilot area.

Table 1: Statistics on maximum differences between weekly noise levels in 2019 and 2020 for the 24 monitoring devices

Indicator	L_{den} dB(A)	L_{night} dB(A)
Maximum difference	11,7	12,8
Minimum difference	1,9	2,2
Average difference	7,3	7,6
Standard deviation	1,9	2,2

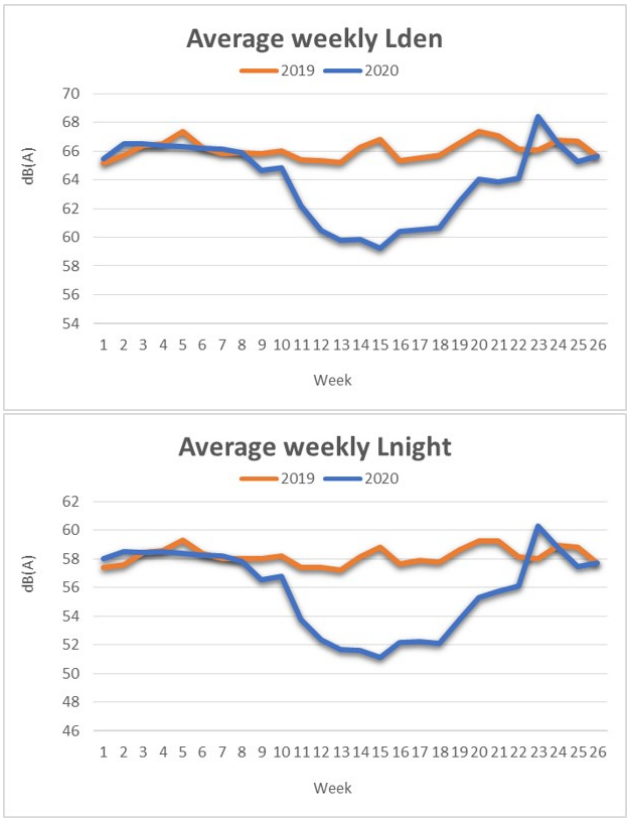


Figure 5: Average noise trend retrieved from the 24 monitoring devices installed in the pilot area of Milan

3.2 Anomalous noise event detection based on ANED

In order to study the effects of the lockdown in the composition of the urban acoustic environment in the District 9 of Milan, the averaged percentage of ANEs identified by the ANED algorithm [14] has been computed and compared between two representative periods: week 12 and week 13 (hereafter denoted as March 2019 and March 2020), considering the differences obtained between a weekday and a weekend day, respectively. To that effect, Wednesday 18th March 2020 has been compared to Wednesday 20th March 2019 (week 12), and Sunday 22nd March 2020 has been compared to Sunday 24th March 2019 (week 13), ensuring that the four days chosen for comparison in a representative period of the lockdown.

As it can be observed from Figure 6, the %ANE decreases by 0.84% on average between March 2019 and March 2020, despite that the difference is so small that may not be significant. However, the pattern differs when comparing the results obtained from the two sampled days. During the weekday the detected reduction is by 1.58%, probably due to the absence of people's activity [10] in

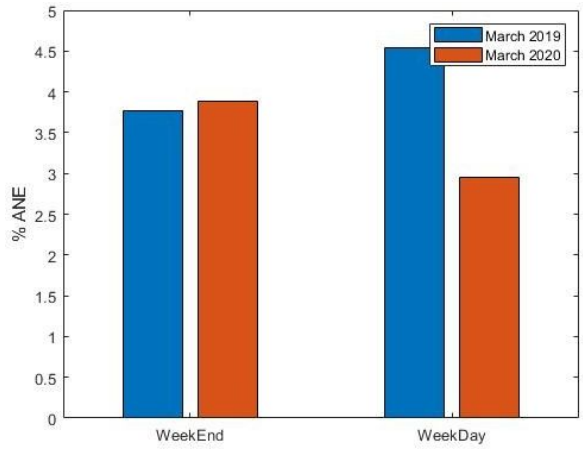


Figure 6: Averaged percentage of ANEs detected through the monitoring network installed in the pilot area of Milan, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

working days, while in weekends the percentage of ANEs remains almost unchanged (increasing only a 0.11%). The aggregated results of this Milan comparison present so slight changes that may not be significant; final conclusion in the urban pilot is that the average performance of the ANED is quite similar to before the lockdown; nevertheless, a detailed analysis of the values in the different sensors present clearer differences.

Next, the distribution of % ANEs detected by the noise monitoring devices is analysed, before and during the lockdown, in working days and weekends, to study in more detail the aforementioned global results.

From Figure 7, it can be observed that most of the detection rates between both periods of time fall within a similar range of percentage values, thus, confirming the results presented in Figure 7. Nevertheless, the figure also shows that the % of ANEs obtained from several sensors is higher during the weekend in March 2020 than in March 2019, being lower for almost all the sensors during the weekday (except for some sensors such as HB133 and HB145). Although most of the monitoring devices present similar patterns between March 2019 and 2020, there are some examples like sensor HB139, that present a different behaviour as the identification of ANEs increases during the weekend, decreasing during the weekday; or sensor HB108, which shows significant lower detection rates during the confinement for both days.

Finally, a couple of examples of the outputs obtained by the monitoring devices presenting the %ANE detection with respect to L_{Aeq} values, which present interesting patterns to complete the global analyses, are included here below for illustrative purposes.

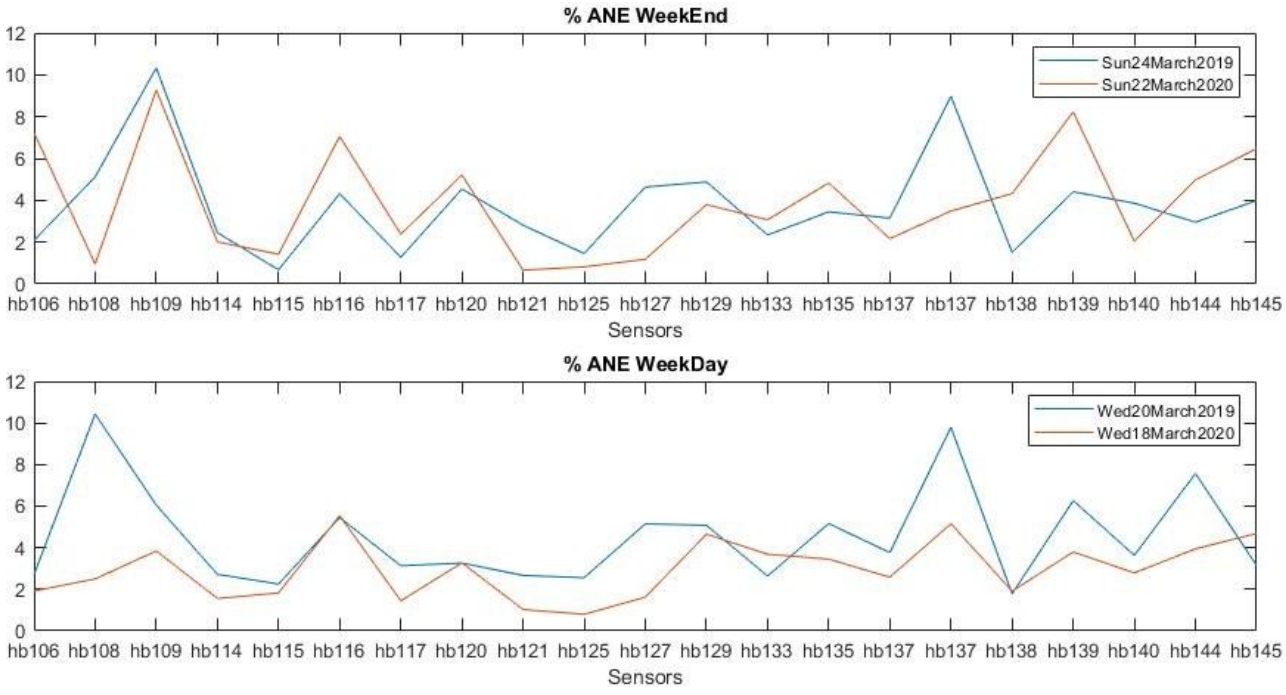


Figure 7: Percentage of ANE detected by each monitoring device installed in Milan pilot area, during a weekday and a weekend day (comparison between weeks 12 and 13 of March 2019 and March 2020)

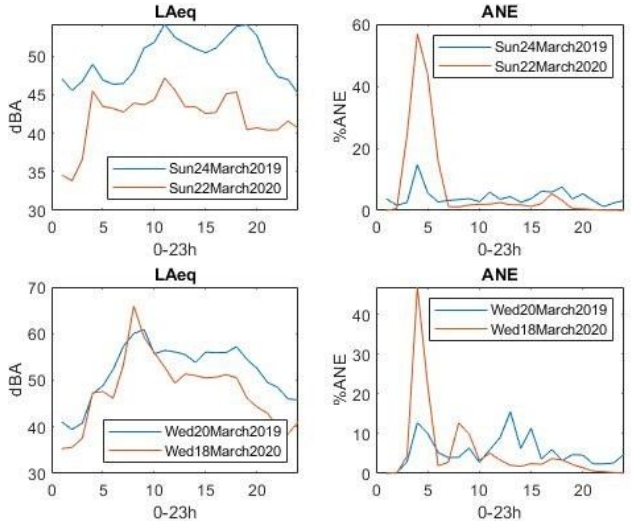


Figure 8: L_{Aeq} values and percentage of ANE detected by the monitoring device HB116 installed in Milan, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

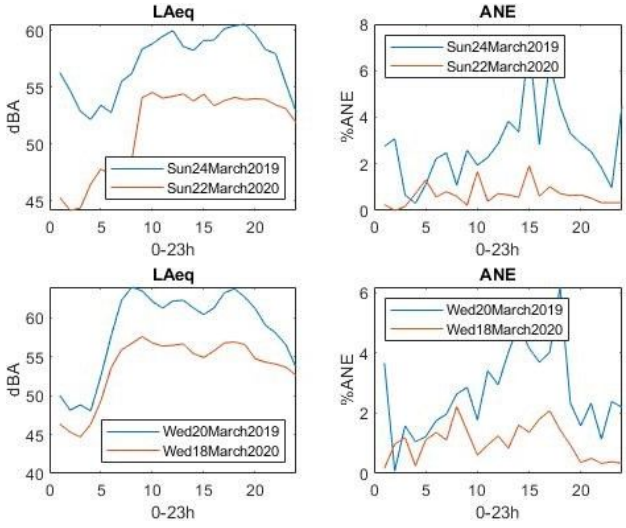


Figure 9: L_{Aeq} values and percentage of ANE detected by the monitoring device HB121 installed in Milan, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

As can be observed from Figure 8, the monitoring device labelled as HB116 shows a quite similar temporal pattern of L_{Aeq} values between 2019 and 2020, but with lower noise levels during the lockdown. Nevertheless, it presents an interesting pattern during the sunrise in 2020 in terms of % ANEs, showing a significant rise in the detection of anomalous noise events in that monitored acoustic environment. The presence of birds in this period of the day may be the main cause of the significant increment of ANEs detected by the ANED algorithm, both during the weekday and the weekend day, especially in the latter, as a conse-

quence of the reduction of RTN levels. However, this hypothesis should be verified in future works.

Figure 9 presents the L_{Aeq} and %ANE obtained from the monitoring device labelled as HB121. Again, the L_{Aeq} values from 2020 are lower than the corresponding pairs in 2019, with a higher reduction during the nocturnal period in the weekend, as also observed in Figure 9. In this case, the percentage of detected ANE also decreases significantly, despite some slight increases during the nocturnal period, most probably due to the very low noise levels present during this period of the day, which makes the presence of ANEs more noticeable. However, it is to note that these differences are lower than 2%, which can be considered as not significant if compared to the L_{Aeq} variation within the same period of time.

4 Traffic noise and impacts on receivers in the suburban area of Rome

The lockdown impact, in terms of flow rate and noise from road traffic, was analysed in a significant portion of the pilot area of Rome, corresponding to the North-East sector of the city, along the Motorway A90 (Figure 10).

Figure 10: Analysed portion of the pilot area of Rome

4.1 Traffic characteristics and trend

The impact of the lockdown period on the mobility of the A90 motorway was assessed accounting for the data collected by ANAS traffic monitoring devices. The observed trend seems to confirm the same behaviour measured across the entire country.

In Figure 11, the weekly average of daily traffic of light and heavy-duty vehicles in 2019 and 2020 are compared. This figure shows a 5% decrease of light vehicles in the period between the last week of February 2020 and the Italian lockdown date, followed by a drastic drop (near 50% of the corresponding values in the same time interval of 2019) in the first week of the lockdown. From week 13, road traffic settled at values equal to about 30% till the end of the lockdown period. During the second phase, from 4 to 31 May 2020, the average daily traffic ratio passed from 64% in the first week, to 66% in the second week and jumped to 77% in the third week. In the fourth week the percentage increased up to 81% to reach a final value of 94% in June 2020.

As for heavy goods vehicles, a slower trend was observed with a 2% decrease in the beginning, followed by a 22% in the next week and a stable value of about 35% over the whole lockdown period. A different trend was observed in the second phase, with fluctuating and not always pos-

Figure 11: Weekly average daily traffic on the road stretch of the A90 under investigation related to light and heavy duty vehicles

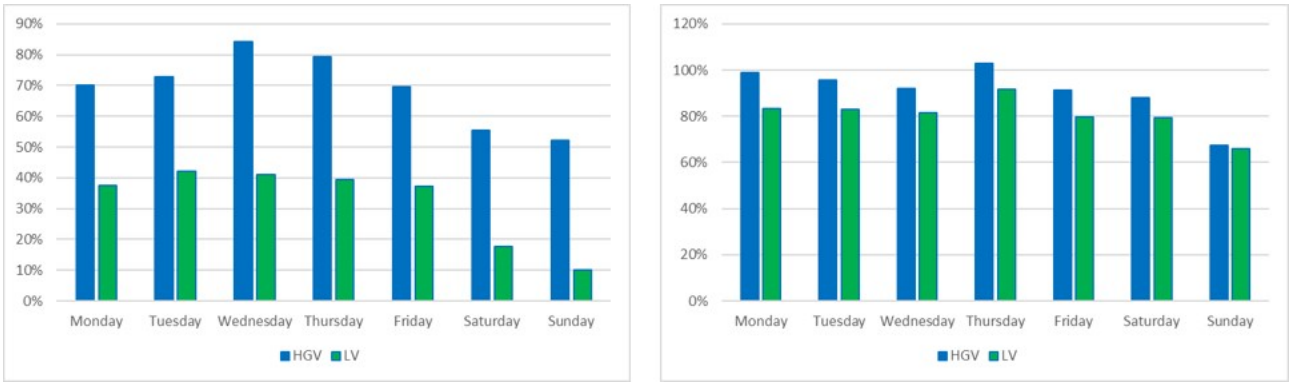


Figure 12: (a) Average daily traffic ratio between 2020 to 2019 in the lockdown period (10 March-3 May) and (b) in the fourth week of the second phase

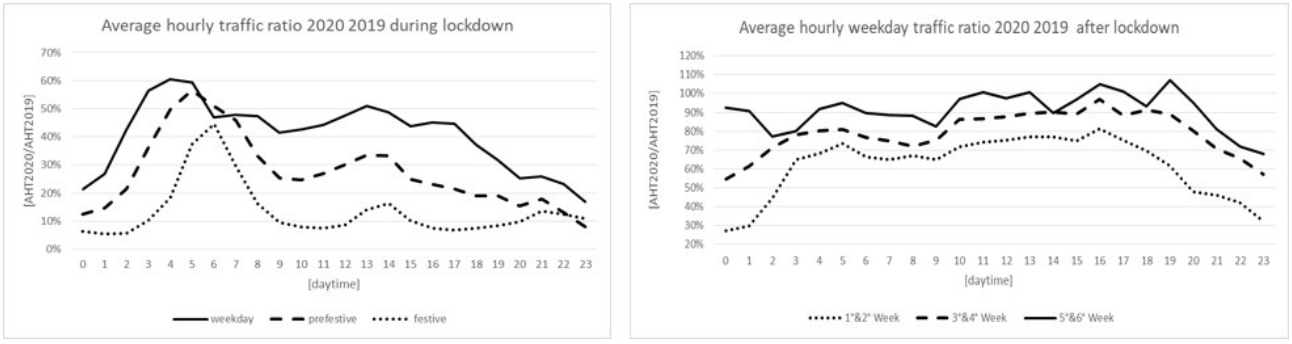


Figure 13: Average hourly traffic ratio between 2020 to 2019 in the lockdown period (10 March-4 May) and in the following weeks [%]

itive variations. During the whole second phase period an average ratio of 75% was observed with peaks of 95% in the second and fourth week.

The main traffic decrease was observed on weekends, particularly on Sundays, when the average total traffic fell by 90% with respect to the same period in 2019, in line with the limitations imposed by the Italian regulations, which allowed only business or strictly necessary travels. During the second phase the trend was almost the same, with corresponding higher values (see Figure 12).

In Figure 13 the hourly traffic distribution is shown. As it can be seen, the main decrease was measured in the evening and at night, with values ranging from 10% to 20% with respect to those detected the year before.

In the second phase the hourly distribution had more or less the same trend, although with gradually increasing levels of traffic.

The decrease in terms of traffic volume led to a considerable increase of the average vehicles speed at daytime, from 90 km/h in 2019 to 110 km/h in 2020, whilst speed remained almost unchanged at night-time.

This trend was rapidly inverted during the second phase, following the increase of traffic volumes.

4.2 Traffic noise

The reduction of traffic volumes gave rise to a corresponding reduction of noise levels. This trend was confirmed by the data detected by the three monitoring devices available in the north-east area of the A90 motorway, with fluctuations depending on local traffic. In Figure 14 the position of the three monitoring devices observed in this study is shown.

In Figure 15 the noise trends related to the European indicators L_{den} and L_{night} from January to June 2019-2020 are compared. The graphs of Figure 15 clearly show the abrupt reduction of noise levels in the lockdown period and the gradual return to normal in the following weeks, from May to June, with larger differences at night.

In Table 2 the maximum, average and standard deviation of the difference between weekly noise levels in 2019 and 2020 is shown. As it can be seen the average difference during the lockdown period is 8,77 dB(A) in terms of L_{den} and 8,67 dB(A) for L_{night}, with peak of almost 10 dB(A) and standard deviations ranging from 1,6 dB(A) and 2,2 dB(A).

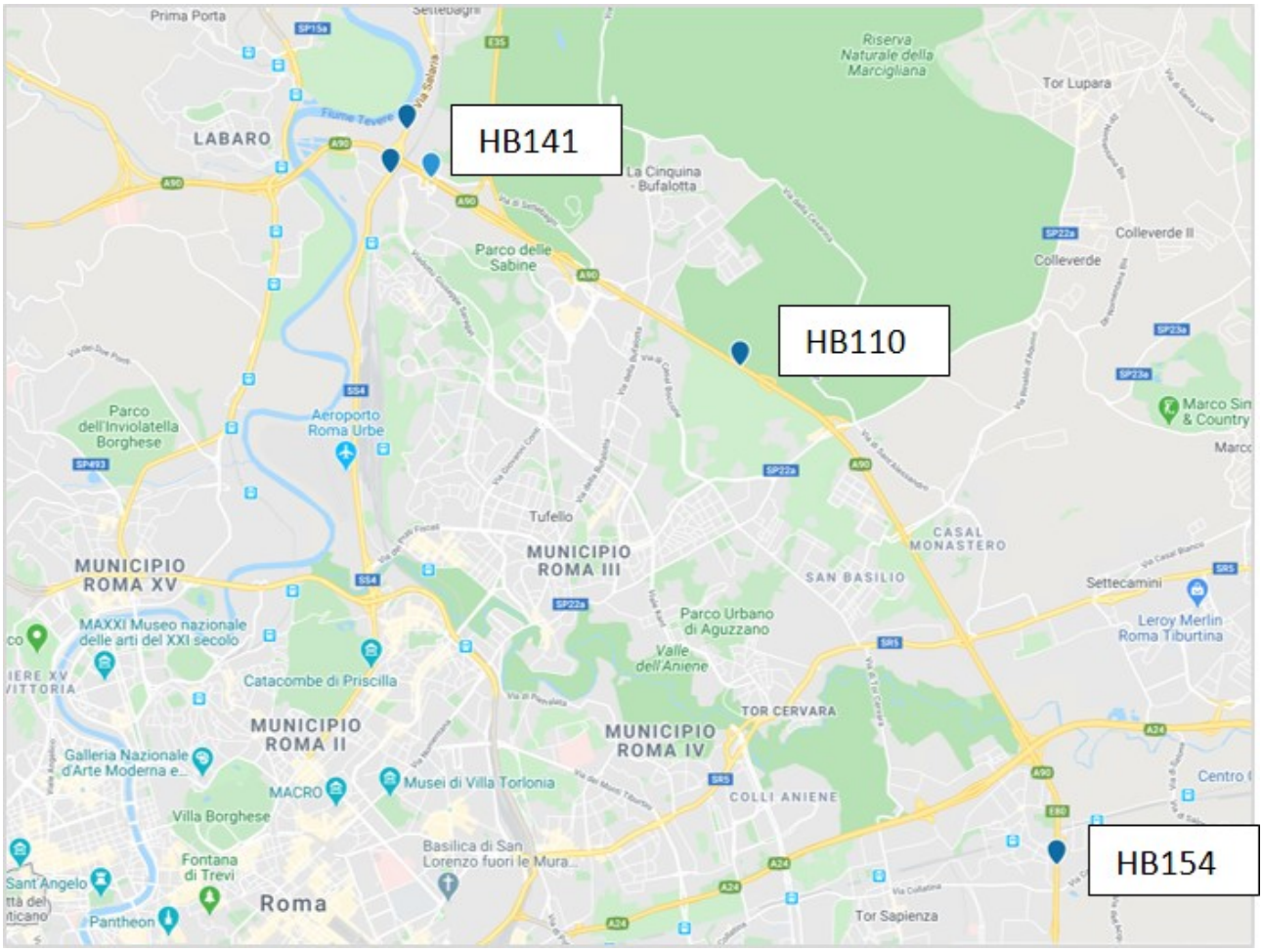


Figure 14: Location of the selected monitoring devices along the road stretch under analysis in the pilot area of Rome

Table 2: Minimum, maximum, average and standard deviation difference between the noise levels in 2019 and 2020

Monitoring Device	Minimum Difference		Maximum Difference		Average Difference		Standard Deviation	
	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}	L_{den}	L_{night}
HB 154	2,6	3,1	9,2	9,4	5,3	5,9	2,2	2,1
HB 141	4,2	4,9	9,4	9,6	5,9	6,2	1,7	1,6
HB 110	2,7	2,6	7,8	7,3	4,5	4,1	1,7	1,6
AVERAGE	**3,2**	**3,5**	**8,8**	**8,8**	**5,2**	**5,4**	**1,9**	**1,8**

4.3 Noise sources classification based on ANED

Following the same methodology described to evaluate the effects of the lockdown in the composition of the urban acoustic environment, this section analyses the averaged percentage of ANEs identified by the ANED algorithm through the monitoring devices installed in the portals of the A90 motorway. Again, the analysis is conducted by comparing the results obtained between the same representative periods (*i.e.*, weeks 12 and 13 of March 2019 and March 2020), considering the differences observed between a weekday and a weekend day.

In general terms, it can be observed from Figure 16 that the lockdown has entailed an average increase of 20.7% in the identification of ANEs. However, it is worth mentioning that this increment is significantly different between the weekend and the weekday, which entail an increase of 43.95% and 11.4% of ANEs detection rate, respectively. This is because some sounds like birdsongs, that were almost impossible to listen with typically high traffic flows before

Figure 15: Noise trend retrieved from the three monitoring devices installed along the road stretch in the pilot area of Rome

the lockdown, became audible also during the day due to the confinement.

Looking into the percentage distribution, a significant increase in the presence of ANEs can be observed during the weekend for all the monitoring devices (see Figure 17). On the contrary, the increment is much lower in the weekday, despite some monitoring stations (*e.g.*, HB112 and HB153) still show quite significant growths. Moreover, it is worth noting the results obtained from HB104 and HB153, which presented the highest values of % ANE in 2019, still entail high ANE detections during the confinement, both at daytime and at night.

Finally, in order to complete the global analyses of the suburban pilot area, two examples of the L_{Aeq} values and the ANE detection rate obtained by two specific monitoring devices (HB134 and HB104) are presented and discussed in the following paragraphs for illustrative purposes.

Figure 18 presents the L_{Aeq} and %ANE obtained from the monitoring device labelled as HB134. It can be observed how the L_{Aeq} values from 2020 are lower than the corresponding pairs in 2019, mainly during the weekend and at night for both days. The percentage of detected ANEs increases significantly during the weekend, especially at night (between 0h and 5h), which is also observed on the weekday. However, the latter presents quite similar percentages at daytime (from 5h to 19h), increasing the identification rate of anomalous events in the evening (also observed during the weekend). These significant increments are in accordance with the substantial decrease of L_{Aeq} within these periods of time, making the presence of any non-traffic-related sound more salient in a silent acoustic environment, for instance, due to the increase of the presence of birds and the easiness to identify their birdsongs due to very low RTN levels.

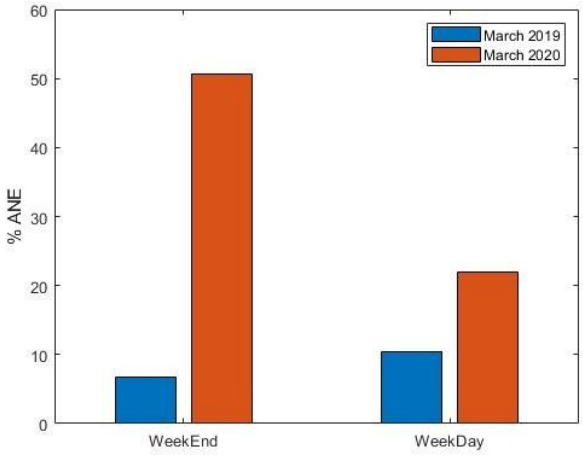


Figure 16: Averaged % of ANE detected through the monitoring network installed in Rome, during the weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

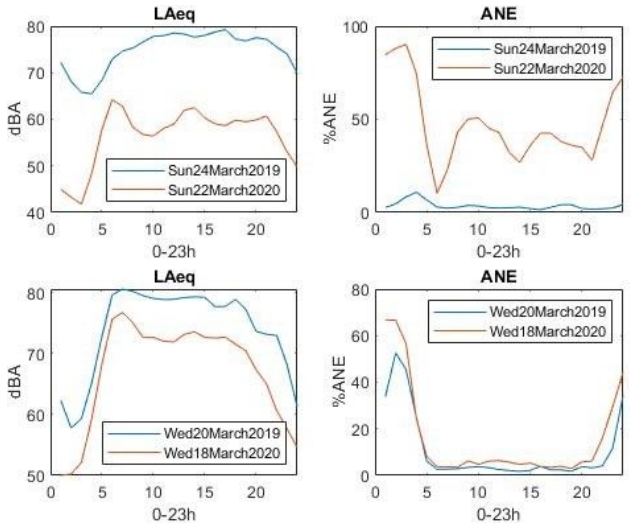


Figure 18: L_{Aeq} values and percentage of ANE detected by the monitoring device HB134 installed in Rome, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

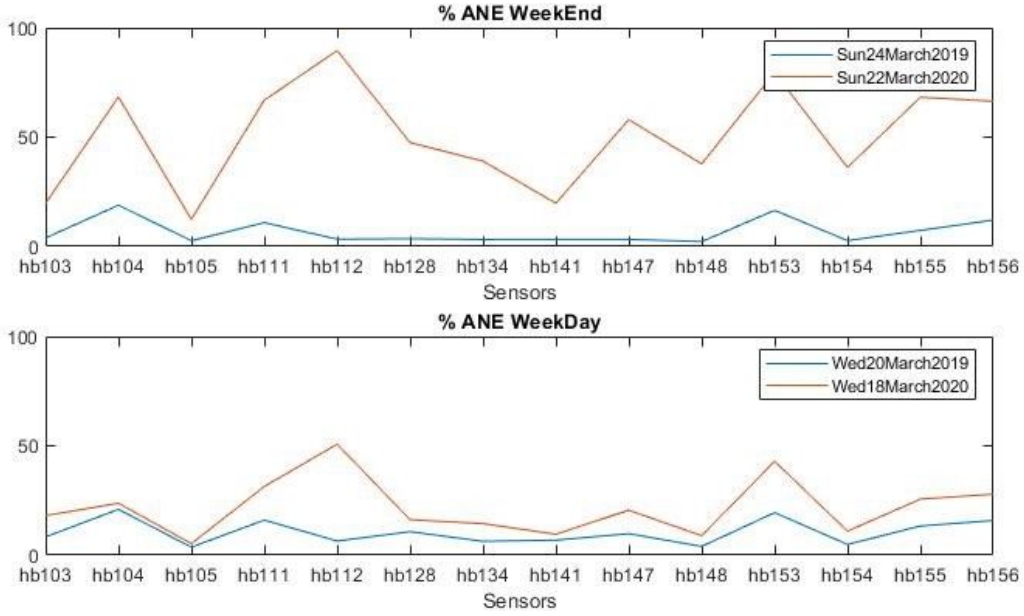


Figure 17: Percentage of ANE detected by each monitoring device installed in Rome, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

Figure 19 shows the L_{Aeq} and %ANE obtained from the monitoring device labelled as HB104. As an overall analysis, quite similar patterns of ANE detection can be observed during the weekday in 2019 and 2020, with very high values at night when L_{Aeq} is lower. The same pattern is also present during the evening, but with lower %ANEs. On the contrary, the %ANE on the weekend is significantly higher at daytime when comparing the considered lockdown period with the same period in 2019. This increase is in accordance with the global decrease of L_{Aeq} levels, due to the consequent RTN levels reduction caused by the confinement. As a particular case, during the weekend in 2020, we can find a peak in the L_{Aeq} curve around 6:00 am, which causes a valley in the corresponding %ANE curve. It is worth mentioning that a similar pattern is also found in Figure 19 during the weekend, maybe as a consequence of an increase of the traffic volume due to some work shift.

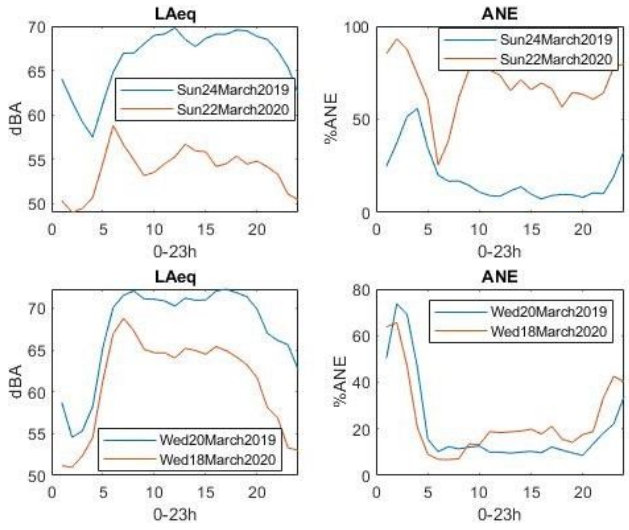
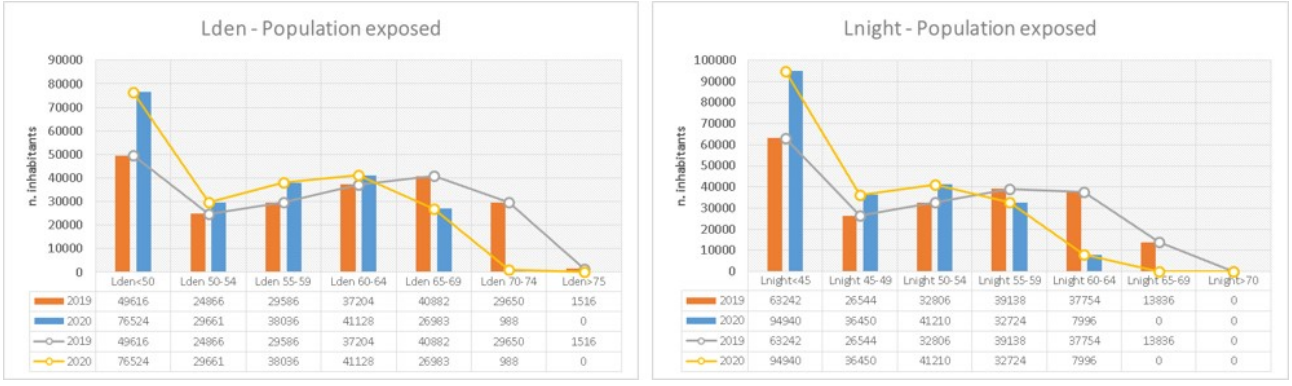


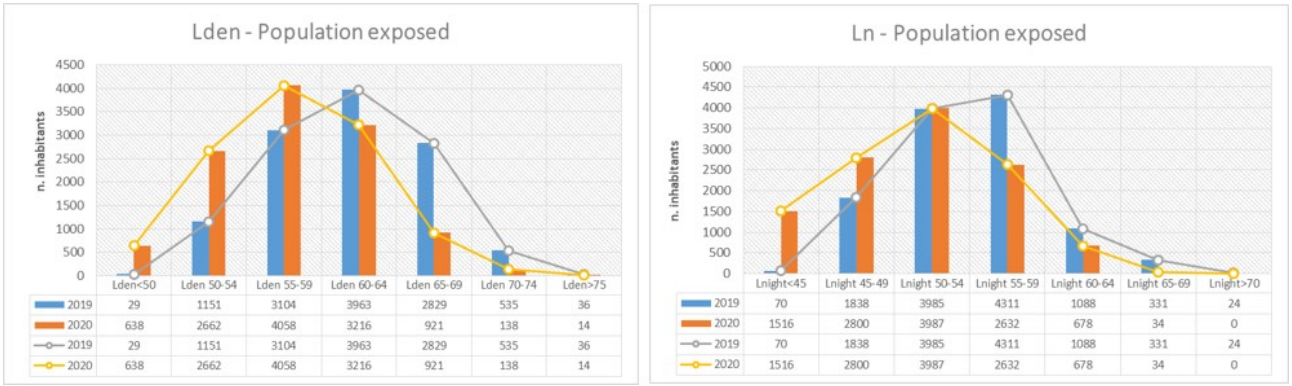
Figure 19: L_{Aeq} values and percentage of ANE detected by the monitoring device HB104 installed in Rome, during a weekday and a weekend day (the comparison is between weeks 12 and 13 of March 2019 and March 2020)

5 Noise impact on population

The noise impact evaluation was made by comparing weekly statistical maps during and after the lockdown (second phase) in the years 2019 and 2020. The evaluation

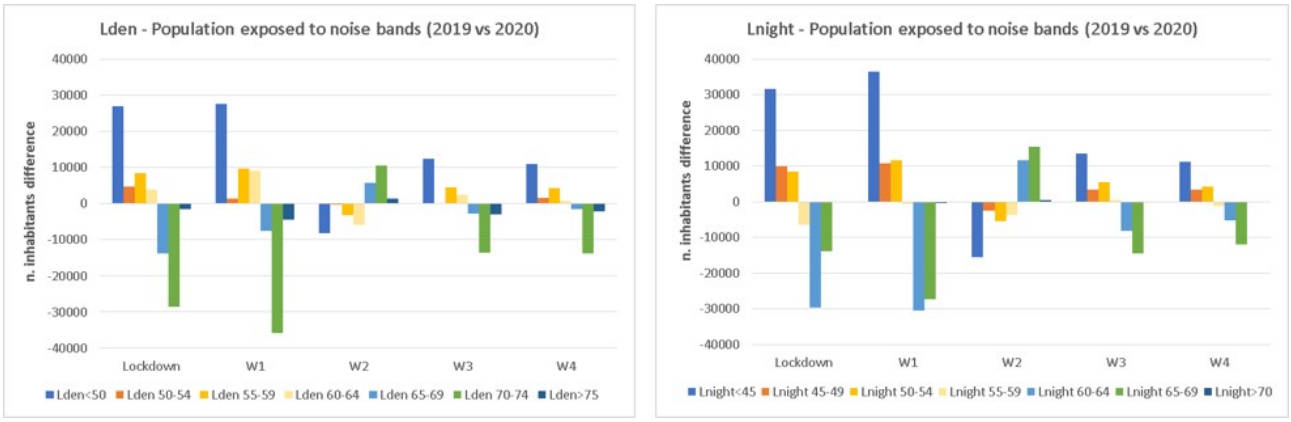


(a)

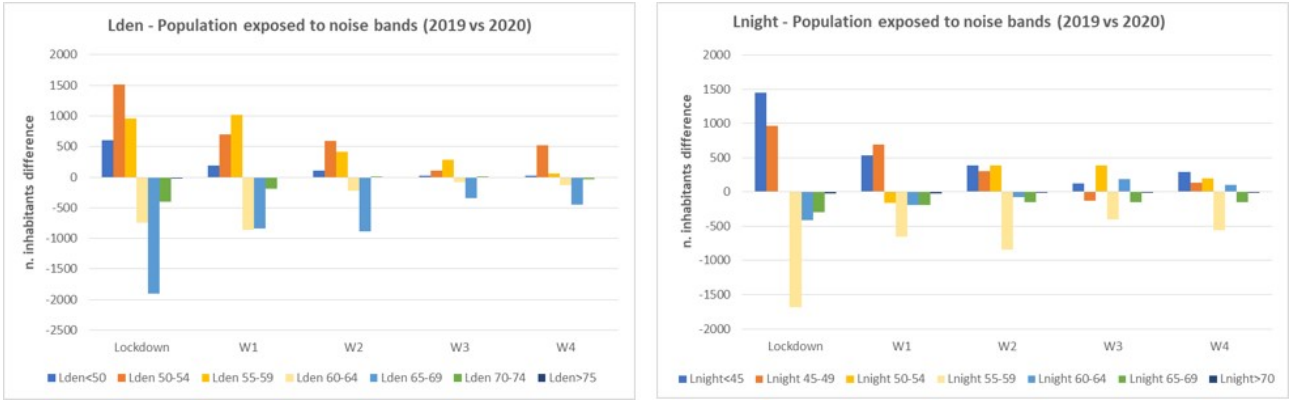


(b)

Figure 20: LOCKDOWN PERIOD - Population exposed to different L_{den} and L_{night} noise bands. a) Milan; b) Rome



(a)



(b)

Figure 21: Difference between the population exposed to different L_{den} and L_{night} noise bands in 2020 and 2019. a) Milan; b) Rome

was focused on the number of people exposed to noise, according to both the END [15] and the Italian legislation. As for the END, the data related to the number of people exposed to environmental noise was distributed over seven noise bands, ranging from 50 dB(A) to 75 dB(A) for L_{den} (L_{den} < 50, 50-54, 55-59, 60-64, 65-69, 70-74, L_{den} > 75), and from 45 dB(A) to 70 dB(A) for L_{night} (L_{night} < 45, 45-49, 50-54, 55-59, 60-64, 65-69, L_{night} > 70). In Figure 20, the data related to the population exposed to L_{den} and L_{night} noise bands throughout the whole lockdown period are shown. These graphs show a shift of the number of people exposed to noise levels from higher noise bands to lower noise bands.

The data analysis procedure applied to the lockdown period was also implemented in the second phase, from May 4th to May 31st. In this case the evaluation was undertaken per weeks, in order to account for the gradual return to normal. In Figure 21 the results related to the number of people exposed to L_{den} and L_{night} noise bands per week, expressed as differences between the values obtained in 2020 with respect to 2019, are shown. Here, the shift towards lower noise bands gradually decreases to finally reach a steady state with usual statistical fluctuations. These graphs also highlight the cut-off noise levels for L_{den} and L_{night}, corresponding to the passage from positive to negative changes. In Milan, the cut-off values are 65 dB(A) for L_{den} and 55 dB(A) for L_{night}, whilst in Rome they are 60 dB(A) for L_{den} and 55 dB(A) for L_{night}.

Figure 21b (Rome case) shows that the reduction of the exposed people above the cut-off values is 42% for both L_{den} and L_{night} during the lockdown. This percentage decreased in the following weeks, reaching a final value at the end of the second phase of 14,4% (L_{den} > 60 dB(A)) and 21, 5% (L_{night} > 55 dB(A)) respectively.

In the pilot area of Milan, the reduction of the exposed people above the cut-off values is 61% for L_{den} and 55% for L_{night} during the lockdown. This percentage decreased in the following weeks, reaching at the fourth week of the second phase the values of 23% (L_{den} > 65 dB(A)) and 20% (L_{night} > 55 dB(A)).

In the pilot area of Rome, the same analysis was performed on the Italian acoustic indicators ($L_{Aeq,d}$ and

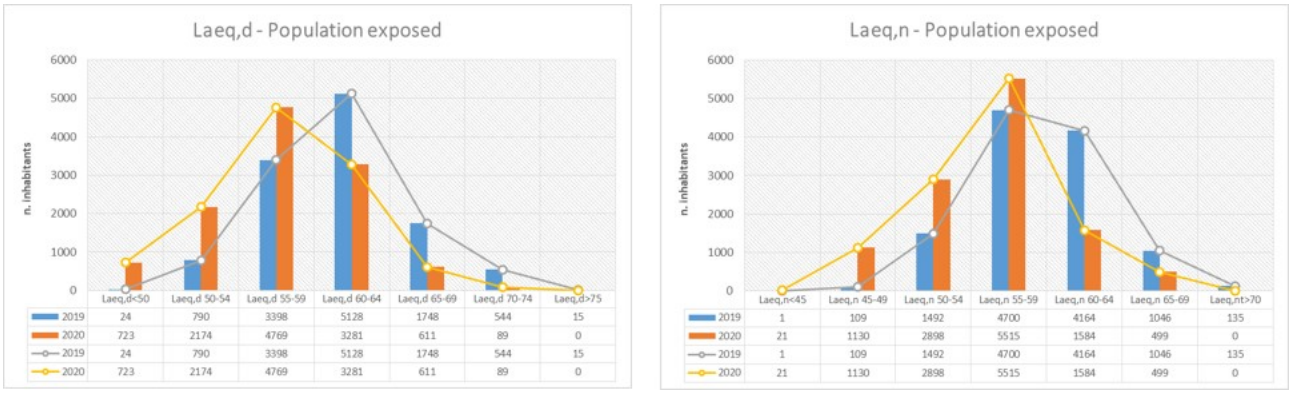


Figure 22: Lockdown period – Population exposed to different $L_{Aeq,d}$ and $L_{Aeq,n}$ noise bands

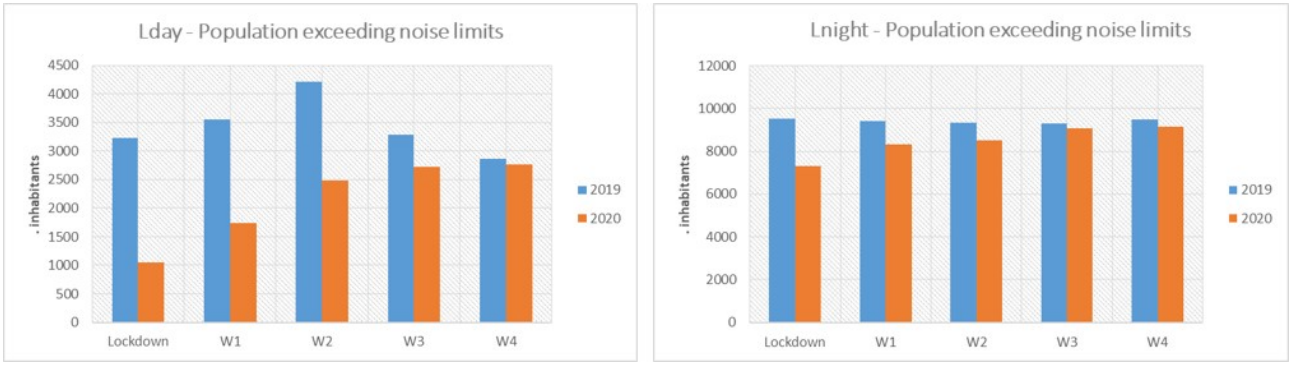


Figure 23: Number of people exposed to noise levels exceeding the Italian noise limits for motorways

$L_{Aeq,n}$), by distributing the number of people exposed to noise levels over seven noise bands, similarly to the European indicators. In Figure 22 the number of people exposed to the different $L_{Aeq,d}$ and $L_{Aeq,n}$ noise bands, related to the lockdown period, are shown. A shift of the exposed population towards lower noise bands can be observed, according to the results achieved for the European indicators.

In Figure 23 the number of people exposed to noise levels exceeding the Italian noise limits for motorways, corresponding to 70 dB(A) at daytime and 60 dB(A) at night, are shown for the whole period, including the four weeks related to the second phase. A significant reduction by 63% was observed during the lockdown period at daytime, being less pronounced the corresponding reduction at night (23%). These graphs also highlight a gradual return to normal conditions in the weeks following the lockdown, which is more pronounced at daytime, when traffic volumes are usually higher.

6 Data analysis and discussion

The data described in the previous paragraphs have shown the effect of the lockdown period on the reduction of noise levels in both the pilot area of Milan (urban environment) and Rome (suburban area), related to the restriction measures and therefore to the drastic reduction of traffic volumes recorded by the monitoring networks. In paragraphs 6.1 and 6.2 the main results achieved are analyzed and discussed.

6.1 The case of Milan

In the pilot area of Milan the lockdown period gave rise to a strong variation in the exposure of the population to noise, with a clear decrease (up to 60% during the lockdown phase) of the population exposed to higher levels (L_{den} > 65 dBA). It is worth noting that the percentage of reduction remains high (about 20%) even after the 4 weeks of Phase 2, highlighting the slow resumption of normal activities and normal traffic conditions, especially in the city of Milan, severely hit by the pandemic.

Particularly, during the lockdown period there was a significant decrease in the weekly noise levels which, for some monitoring devices, reached values of about 12 dB, both in terms of L_{den} (whole day) and L_{night} (only the night period). On average, a decrease of about 7 dB was detected, thus highlighting the fact that the road network is composed of streets with different traffic features (vehicle flows, types of vehicles, average speeds and use).

6.2 The case of Rome

As for Rome, the results achieved clearly demonstrate a consistent reduction of noise levels, especially during the lockdown phase (8,7 dB(A)), with respect to the same period in 2019, despite the increase of vehicle speed of about 20 km/h, due to free flowing conditions. This led to a corresponding reduction in the number of people exposed to higher noise bands and less people exposed to noise levels exceeding noise limits by 63% during the day and 23% at night, when traffic is usually lighter.

The reduction of noise levels made the acoustic environment change, with nature related sounds detected as anomalous noise events (mainly birds), also along a very trafficked road as the A90 Motorway. This made people able to appreciate the sound of silence and to clearly perceive unexpected sounds.

With the lockdown release, gradually the soundscape came back to normal and the shift towards lower noise exposure bands progressively decreased until a steady state noise scenario with expected statistical fluctuations, also due to variable meteorological conditions, was reached (see Figure 21).

7 Conclusions

In this paper the effects of the lockdown and of the following reopening phase in the cities of Milan and Rome has been analysed in terms of traffic, soundscape (as anomalous noise events), noise levels and related impact on receivers.

In Milan the acoustic environment was analysed by collecting and averaging the information retrieved from 24 monitoring sensors, distributed all over the pilot area, in the years 2019 and 2020, within a time frame ranging from March to June. The results achieved show an average difference in noise levels of 7 dBA, with peak values of 12 dB(A) in particularly silent areas. This led also to a decrease (up to 60% during the lockdown phase) of the population exposed to higher noise levels (L_{den} > 65 dBA). As for anomalous noise events, it was observed a reduction of ANEs in 2020, with respect to the same period in 2019, due to the absence of human activities along the streets in working days. On the contrary, ANEs detection during weekends remained unchanged, showing that weekends are quiet anyway even before the lockdown.

In Rome the study was undertaken to a portion of the monitoring network (north-east sector of the ring road, Motorway A90), representative of the acoustic climate of the whole infrastructure. In this case, an average noise levels difference of 8,80 dBA during the whole day and 8,77dBA at night has been observed in the reference period. This led to a corresponding reduction in the number of people exposed to higher noise bands and less people exposed to noise levels exceeding noise limits by 63% during the day and 23% at night, when traffic is usually lighter.

As for anomalous noise events, an increase of 20% in the detection of ANEs, both in working days and weekends has been noticed in the Rome pilot, while in Milan pilot we can consider that the detection of ANEs has remained the same as before the lockdown (with a slight noticeable decrease in the weekday). This was due to lower background noise levels, that made ANEs (as birdsong, industry noise, etc.) being perceived even close by a very trafficked road, as the Motorway A90. A challenging future line in terms of ANED development could be to gather new raw acoustic data from the sensors in order to re-train the algorithm with the new acoustic environmental conditions. It is also interesting to note that for both areas Milan and Rome, the difference between noise levels (maximum and average) in the reference period is more or less the same at night (L_{night}) and during the whole day (L_{den}).

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