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On the perception of Limited Traffic Zones as urban noise mitigation action

Abstract: Environmental noise is a very important issue in modern urban agglomerations and new policies are being explored in order to reduce high sound-pressure levels from transportation and industry, especially in urban contexts. Considering this issue from the subjective perspective, environmental noise is often related to noise annoyance. Over the years, possible solutions were explored for urban sound planning beyond the mere noise control engineering techniques and a number of international projects proposed innovative approaches to deal with this issue: most of them were traffic-related. In order to support the city management, it is suitable to analyse possible indirect effects of traffic limitations on the perception of the sonic environment. Indeed, it was observed that even traffic management plans with no specific focus on noise mitigation are likely to have acoustic implications. The present study investigated the variations of the sonic environment induced by the implementation of a Limited Traffic Zone (LTZ) in the historic centre of Naples, in terms of objective parameters and perceived quality of the ‘sound’ component by means of noise and social surveys before, immediately after and one year after the LTZ implementation, in order to check for possible time effects. Results show that the sample interviewed immediately after the LTZ implementation reported overall positive opinions on the sonic environment and its variation, while the sample interviewed one year after tended to shift to more neutral opinions. This finding suggests that the LTZ could be considered an effective environmental strategy for the urban noise control, but it should be adequately actuated in order to preserve the achievements in terms of noise reduction and subjective perception by the local population.

Keywords: Limited Traffic Zones; Environmental Noise; Noise perception; Urban soundscape

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1 Introduction

Noise pollution is a major issue in modern cities and it is affecting the overall quality of the acoustic environment. One of the main challenges for local authorities is controlling high sound-pressure levels from transportation and industry. Traffic noise sources are often referred as the most relevant components of environmental noise and were proved to have a significant impact in urban agglomerations (e.g. [1]). The 2002/49/EC Directive – often referred as Environmental Noise Directive (END) – provides that the Member States of the European Union must protect ‘quiet areas’ [2]. Nevertheless, the guidelines for the definition of quiet areas were vague, so the Member States have requested additional guidance. In 2012 the European Parliament acknowledged that the vague definition of quiet areas in the END leaves room for interpretation, which has led to confusion and diverse approaches to the protection of quiet areas. The European Environment Agency (EEA) published a ‘Good practice guide on quiet areas’ in 2014 [3]. It recommends four complementary methods for identifying quiet areas: (1) noise mapping, (2) sound level measurements, (3) the soundscape approach, and (4) expert assessments. Similarly, it points out the need for further data on perceived acoustic quality. By approving the Directive 2002/49/EC, the European Parliament and the Council urged the Member States of the European Union to monitor sound-pressure levels from transportation and industry, and to implement action plans for noise mitigation in urban agglomerations [2]. Due to an increasingly phenomenon of densification of cities (and therefore of noise sources), noise mitigation actions in urban contexts became more urgent [4]. Therefore, ‘urban acoustics’ has been given more attention in recent years (e.g. [5]). Researchers have focused on developing
models for sound propagation in urban scenarios, taking into account specific context-related effects such as street canyons (e.g. [6]), reflections from building façades (e.g. [7]) or traffic flow dynamics (e.g. [8–10]).

From the subjective viewpoint, environmental noise is likely to trigger psycho-physiological stress responses, thus legislation frameworks provide that sound-pressure levels from transportation and industry must be reduced below defined thresholds [4]. Generally, environmental noise is related to noise annoyance [4] that can be seen as a perceptual construct overlaying a negative assessment of the sonic environment. Guski et al. [11] defined noise annoyance as a “multifaceted concept, covering mainly immediate behavioural noise-related effects and evaluative aspects”. Consequently, the possibility to collect individual responses to noise annoyance is essential for assessing the impact of noise and for this reason it has been comprehensively investigated (e.g. [11–15]). Paunovic et al. [16] and Jakovljević et al. [17] suggested in their studies that it is possible to predict the percentage of highly annoyed in urban residents by subjective noise sensitivity, independently from noise exposure. Furthermore, the authors found that having windows oriented toward the street and noise annoyance at workplace are also non-accoustical predictors of noise annoyance in noisy streets, whereas the average time spent daily at home was the only significant predictor of noise annoyance in quiet streets.

Nevertheless, controlling the sound-pressure levels from certain sound sources for reducing noise annoyance may not necessarily result in an acoustic environment of high quality, because the character of the sound is equally important [18]. Yang & Kang [19] investigated possible factors influencing the individual assessment of the sound level and the assessment of the acoustic comfort. The background noise level was found to be negatively correlated with the perceived soundscape quality in urban open public spaces and acoustic comfort was affected by the sound source type. However, in urban contexts, there are many different factors to consider, other than noise itself, to achieve what was recently defined as ‘acoustic sustainability’ [20]. Yu & Kang [21] investigated the effect of social, demographical, physical, behavioural and psychological factors on the sound preference evaluation in nineteen cities in Europe and China. The authors observed that age and education level are correlated with the preference of natural sounds and annoyance from mechanical sounds; more specifically: with increasing age or education level, overall, people tend to prefer natural sounds and are more sensitive to mechanical sounds. Furthermore, the preference for a place was found to be a factor of influence on sound preference.

Consequently, over the years, researchers investigated possible solutions for urban sound planning beyond the mere noise control engineering techniques and a number of international projects proposed innovative approaches to deal with this issue. The ‘CITYHUSH’ project proposed and validated the implementation of a ‘Quiet zone’ (Q-zone). The project verified different test sites having different traffic conditions around Europe [22]. In these Q-zones, low sound-pressure levels from traffic noise were maintained by permitting the transit of only low noise vehicles. For this purpose, five different noise classes for vehicles were proposed, ranging from class A (quietest class), to class E (noisiest class).

In general, several cities have implemented measures related to traffic noise specifically focused on noise reduction. The City of London adopted a strategic plan [23] in which particular attention was reserved to noise management for all traffic operations. It includes implementations such as training programmes for bus drivers for reducing noise emissions, acquisition of quieter vehicles for the public transportation system, application of quieter warning signals for heavy vehicles at night-time, traffic restrictions within the city centre.

On the other hand, also traffic management plans with no specific focus on noise mitigation are likely to have acoustic implications. So far, an increasing number of cities have implemented policies for traffic mitigation. For the purpose of urban sustainability, Access Restriction Schemes (ARSs) can result to be very powerful tools. In urban contexts they have the main aim of preventing the access for specific categories of vehicles. Limited Traffic Zones (LTZs), Low Emission Zones (LEZs), Low Speed Zones (LSZs) or Pedestrians Areas are few examples of such schemes. More specifically, the LTZ is a traffic management strategy increasingly adopted by municipalities to improve their environmental conditions. This scheme is not based on the type of vehicle, but rather on the users: it generally prevents most of private vehicles from accessing a specific area.

2 Objectives

In 2012, the City of Naples implemented in its historic centre one of the largest European LTZ (1.16 km²). This traffic regulation prevents private vehicles (with the exception for motorcycles) from entering and circulating within the area, every day from 09:00 am to 06:00 pm. Residents and special categories (e.g. police, emergency vehicles) are excluded from the restriction. Due to its very peculiar nar-
row streets, the historic centre is provided with no regular public transportation lines. This initiative of the City Council was supported by a massive informative campaign for the public, mainly focused on the advantages that such a policy was supposed to achieve in terms of air quality and urban safety. Despite of the lack of ‘political’ consideration, the LTZ also implied significant consequences for the acoustic environment of Naples historic centre [24–26].

The present study was meant to assess how the variations of the sonic environment induced by the LTZ implementation were perceived by residents and to investigate whether there was a time effect on a change of opinions to this regard. The hypothesis to test was that residents would assess differently the effectiveness of the traffic limitation action, depending on time. Indeed, previous findings in literature show that individual attitudes to environmental noise are likely to vary over time: Skinner & Grimwood [27] compared the measurement of environmental noise levels and the responses to a social survey about people’s attitudes to environmental noise in the UK, from two data collection campaigns over a 10-year time (1990-1991 and 1999-2001). In their comparative study, noise levels’ variations between 1990 and 2000 were found to be consistent with an increased number of noise producing events (i.e. more vehicles), even if with a lower noise output from each event (i.e. quieter vehicles). Regarding the social survey, they observed that over the considered 10-year time, there was an increase in the percentage of people reporting being adversely affected by noise from their neighbours, as well as an increase in the percentage reporting hearing several specific types of traffic noise. Likewise, time is a factor that is likely to affect the perceived effectiveness of some noise mitigation tools. In his study on the design of noise barriers, Bendtsen [28] observed an ‘adaption effect’, reporting that residents living close to noise barriers tended to forget quickly the noise levels that they were exposed to before the mitigation intervention and become rather dissatisfied due to the loss of view.

The main reason for this study was to test the perceived effectiveness of a traffic management action as an indirect noise mitigation action. The focus of the current research doesn’t overlie on the soundscape of the historic centre of Naples –for which some references in literature are already available– but rather on the outcomes of a specific traffic policy on the perception of the sonic environment.

Three in situ measurement campaigns were carried out immediately after the LTZ implementation (January 2012), immediately after the LTZ implementation (February 2012) and one year after the LTZ implementation (February 2013), whereas two in situ social surveys were carried out immediately after and one year after the LTZ implementation with two different groups of residents. The reason for not having carried out the social survey also in January 2012 is that the experimental design was conceived for assessing the perceived improvement provided by the LTZ, rather than assessing the actual effectiveness of the LTZ itself as a noise mitigation action. The focus of the research was on the perceived ‘variation’, therefore the individual responses for the before-LTZ condition would have served no purpose within the framework of this study. Individual responses were collected about the current situation and the perceived environmental variations introduced by the LTZ by means of structured questionnaires. The main evidences are presented and discussed.

### 3 Methods

#### 3.1 Study area

The study area is located in the historic centre of Naples. It corresponds to the Limited Traffic Zone (LTZ) as implemented by Naples City Council on February 2012. Due to its particular urban morphology and historic, as well as social interest, the sonic environment of this area had been previously investigated in several researches (e.g. [29–31]). The historic centre of Naples is a grid of perpendicular streets (‘decumani’ and ‘cardini’), that is a consequence of the ancient Greek and Roman street systems. Within the study area, ten paths were considered for further analysis (Fig. 1).

![Figure 1: Naples Historic Centre: the LTZ in green and the selected paths for data collections.](image-url)
The set of selected paths covers most of this urban structure: it includes the four ‘decumani’ (main parallel streets in the west-east direction; namely: Anticaglia, Tribunali, S. Biagio and Giusso) and six ‘cardini’ (secondary parallel streets in the north-south direction, perpendicular to the ‘decumani’; namely: S. Sebastiano, Mezzocannone, Paladino, S. Paolo, S. Gregorio, Miroballo). These paths were considered to be representative for the historic centre, as they are the most relevant in terms of presence by both residents and tourists (Fig. 2).

Figure 2: Examples of streets in the historic centre of Naples: ‘Tri- bunali’ (A), ‘S.Biagio’ (B) and ‘S.Gregorio’ (C).

### 3.2 Data collection

Three in situ campaigns were conducted: before the LTZ implementation (January 2012), immediately after the LTZ implementation (February 2012) and one year after the LTZ implementation (February 2013). For the purpose of this study, considering the LTZ implementation in February 2012, the three periods January 2012, February 2012 and February 2013, will be referred as ‘ANTE’, ‘POST’ and ‘POST+1’ conditions, respectively.

Data collection consisted of two stages: binaural recordings and social surveys. Binaural recordings were carried for the ANTE, POST and POST+1 conditions, whereas social surveys were carried out for the POST and POST+1 conditions.

#### 3.2.1 Binaural recordings

The binaural recordings were made by means of a portable device (M-Audio Microtrack 24/96) connected to a binaural microphones headset (Sennheiser HDC 451). The operator wore the headset and walked normally on the ten selected paths at a speed of 2 steps/s. Recordings were made during working days, between 10:00 am and 12:00 pm, in the same day and lasted between 5 and 10 minutes, depending on the length of the path. Weather conditions were good (no rain) and the wind speed didn’t exceed 5 m/s. Every path corresponded to an audio recording, therefore ten audio samples were collected and for each of them the noise levels were calculated. The same procedure was repeated for the ANTE, POST and POST+1 conditions. Typically, soundscape studies include binaural recordings carried out at fixed positions (e.g. [32–34]); nevertheless, it is worth pointing out that ‘dynamic’ recordings could be more representative of the actual perception of the urban sonic environment. Indeed, in urban contexts, people are more likely to ‘walk across’ the space, rather than ‘stay’ in fixed positions, therefore the changes experienced because of the movement should also be represented at the recording stage. This approach is also supported by some references in literature (e.g. [35]) where it has been highlighted that the perception of changing in sound environment due to sudden variations of noise levels (like those experienced due to movement) are a crucial parameter to consider for the individual environment assessment.

#### 3.2.2 Social surveys

Two different groups of persons were interviewed in the POST and the POST+1 condition. Interviews were carried out in situ, in the same days of the binaural recordings. Participants’ inclusion criteria were ‘being resident within the LTZ’ and/or ‘working or studying within the LTZ’. Interviewees were anonymous and informed consent was obtained in advance. Participants were approached by two experimenters in random locations within the network of the ten selected paths. Demographic information (gender, age) was collected for descriptive purposes and it is reported in Table 1 for both the POST and the POST+1 conditions. In the POST condition, participants’ number and demographic characteristics were functional to the people that two experimenters were able to interview during the same time slot of the binaural recordings. Consequently, in the POST+1 condition, the experimenters aimed at achieving a similar sample.

Participants were required to answer to two questions: (Q1) ‘Currently, how would you assess the following environmental aspects?’ and (Q2) ‘Considering the before-LTZ conditions, how would you assess the variation of the following environmental aspects?’ For both questions (Q1) and (Q2), participants had to assess 4 environmental aspects – air quality, cleanliness, safety, sound – on a 7-point scale ranging from ‘very bad’ (1) to ‘very good’ (7). It is worth noticing that even if the main focus of this study was on the perception of the sound environment, this circumstance was never mentioned to interviewees, in order to avoid possible effects of preconception of the participants with respect to environmental noise issues. Participants
Table 1: Characteristics of the subjects participating to the interviews for both the POST and the POST+1 conditions.

| Gender | Age groups | Inclusion criterion |
|--------|------------|---------------------|
|        | 18 – 30    | 30 – 40             | 40 – 50 | 50 – 60 | >60 |
| POST   | male       | 44                  | 12      | 12      | 8   | 7   | 5   | 20  | 24  |
|        | female     | 25                  | 5       | 7       | 9   | 1   | 3   | 7   | 18  |
| POST+1 | male       | 39                  | 9       | 15      | 6   | 2   | 7   | 22  | 17  |
|        | female     | 30                  | 7       | 12      | 2   | 5   | 4   | 14  | 16  |

were simply informed that the aim of the research was to collect some comments from the general public about the implementation of the LTZ.

4 Results

4.1 Binaural recordings

The noise levels ($L_{Aeq}$, $L_{95}$, $L_{50}$, $L_5$) were calculated for each of the 10 recordings corresponding to the 10 selected paths, for the ANTE, POST and POST+1 repositories. Noise levels were calculated separately for left and right channels and the mean of the two channels’ result was considered. The average noise levels were afterwards calculated over the 10 audio recordings. The average $L_{Aeq}$ were: 70.5 dB(A) for the ANTE condition, 67.3 dB(A) for the POST condition and 70.9 dB(A) for the POST+1 condition. Thus, even though the levels’ distributions are only representative of the in situ campaigns conditions, it is worth observing a general decrease over January 2012 and February 2012 of 3.2 dB(A) and an increase over February 2013 of 3.6 dB(A), bringing the sound levels to the same sound levels as measured before the implementation of the LTZ.

4.2 Social surveys

The results of the social surveys were analysed separately for the two in situ campaigns (POST and POST+1). Regarding the four considered environmental aspects (‘air quality’, ‘cleanliness’, ‘safety’ and ‘sound’), participants were required to assess both the current situation (see Q1) and the variation they perceived with the respect to the ‘before-LTZ implementation’ condition (see Q2).

Figure 3: Noise levels distributions of the ten selected for the ANTE, POST and POST+1 conditions.

4.2.1 February 2012: POST condition

Fig. 4 shows the individual responses’ distributions of the four considered environmental aspects immediately after the implementation of the LTZ (POST). It can be observed that ‘sound’, overall received more positive assessments with respect to the other proposed environmental aspects, with very few interviewees assessing negatively the sound environment. Therefore, in the short-term assessment, the interviewed sample acknowledged the drop of noise levels due to the LTZ implementation and had a positive attitude towards it.

Regarding the perceived variation with respect to the ‘before-LTZ implementation condition’, the ‘sound’ also performed very well, compared to an overall neutral trend for the other environmental aspects (Fig. 5). Interestingly, in terms of positive assessments, ‘sound’ even performed better than the ‘air quality’ element, on which the informative campaign of the City Council was mainly focused.
4.2.2 February 2013: POST+1 condition

Fig. 6 shows the individual responses’ distributions of the four considered environmental aspects one year after the implementation of the LTZ (POST+1). The number of participants expressing a positive assessment for the sound environment dropped dramatically, while the distributions for the other environmental aspects didn’t change significantly. Thus, regarding the assessment of the sound environment, the individual responses seem to be consistent with the observed increase of the noise levels.

On the other hand, regarding the perceived variation with respect to the ‘before-LTZ implementation condition’ one year earlier, the ‘sound’ still performed good when compared to the other environmental aspects, but the neutral opinions were much more dominant overall (Fig. 7). So, part of the sample is still assessing in a positive way the variation of the sonic environment with respect to the ‘before-LTZ implementation’ condition, despite of the increase of the noise levels.

4.2.3 Statistical analysis

In order to test whether the differences observed in the rates for Q1 and Q2, between the POST and POST+1 conditions, were statistically significant or rather random, two chi-square tests of independence were performed to examine the relation between ‘time’ (POST and POST+1 conditions) and the individual responses. The first test of independence tested the relation between ‘time’ and the ‘current sound environment’ rates (Q1). This relation was found to be significant: \( \chi^2 (6, N = 138) = 28.075, p < .01 \). Another chi-square test of independence was then performed to examine the relation between ‘time’ and the ‘perceived variation of the sound environment’ rates (Q2); likewise, the relation was found to be statistically significant: \( \chi^2 (6, N = 138) = 23.002, p < .01 \). Thus, there was ‘time’ effect on people’s perception of the sound environment quality and the perception of the sound environment quality variation over the year after the implementation of the LTZ. In Table 2, the observed and expected variations over the rating scale have been reported for both Q1 and Q2.
Table 2: The observed and expected variations over the rating scale reported for both Q1 and Q2.

| TIME * SOUND_CURRENT Crosstabulation |          |          |          |          |          |          |          |
|--------------------------------------|----------|----------|----------|----------|----------|----------|----------|
|                                      | very bad | nor bad  | not good | very good| Total     |          |          |
| POST                                 | Count    | 9.0      | 1.0      | 3.0      | 15.0      | 16.0     | 14.0     | 11.0     | 69.0     |
|                                      | Expected Count | 7.0      | 4.5      | 9.5      | 18.0      | 13.5     | 10.5     | 6.0      | 69.0     |
| POST+1                               | Count    | 5.0      | 8.0      | 16.0     | 21.0      | 11.0     | 7.0      | 1.0      | 69.0     |
|                                      | Expected Count | 7.0      | 4.5      | 9.5      | 18.0      | 13.5     | 10.5     | 6.0      | 69.0     |
| Total                                | Count    | 14.0     | 9.0      | 19.0     | 36.0      | 27.0     | 21.0     | 12.0     | 138.0    |
|                                      | Expected Count | 14.0     | 9.0      | 19.0     | 36.0      | 27.0     | 21.0     | 12.0     | 138.0    |

| TIME * SOUND_VARIATION Crosstabulation |          |          |          |          |          |          |          |
|---------------------------------------|----------|----------|----------|----------|----------|----------|----------|
|                                      | very bad | nor bad  | not good | very good| Total     |          |          |
| POST                                 | Count    | 3.0      | 1.0      | 1.0      | 12.0      | 12.0     | 27.0     | 13.0     | 69.0     |
|                                      | Expected Count | 1.5      | 0.5      | 0.5      | 21.5      | 8.0      | 20.5     | 16.5     | 69.0     |
| POST+1                               | Count    | 0.0      | 0.0      | 0.0      | 31.0      | 4.0      | 14.0     | 20.0     | 69.0     |
|                                      | Expected Count | 1.5      | 0.5      | 0.5      | 21.5      | 8.0      | 20.5     | 16.5     | 69.0     |
| Total                                | Count    | 3.0      | 1.0      | 1.0      | 43.0      | 16.0     | 41.0     | 33.0     | 138.0    |
|                                      | Expected Count | 3.0      | 1.0      | 1.0      | 43.0      | 16.0     | 41.0     | 33.0     | 138.0    |

Considering the rates distribution of the ‘current sound environment’ (Fig. 8), part of the sample shifted from positive rates (‘very good’) to more neutral and negative rates (‘nor bad nor good’) between the POST and POST+1 conditions.

Similarly, Fig. 9 shows that, as regards the rates for ‘variation of the sound environment’, part of the sample moved from positive to neutral viewpoints after one year from the LTZ implementation. Fig. 9 also shows that both groups of participants agreed in assessing that no negative variation of the sonic environment had occurred.

5 Discussion and conclusions

In this study, ‘dynamic’ binaural recordings were carried out to monitor the overall sonic environment in the historic centre of Naples before, immediately after and one year after the implementation of a Limited Traffic Zone; the rationale for this method was considering the perception of a person walking, instead of a ‘static’ approach that is rather typical for classic noise monitoring. The analysis of the average noise levels over time revealed a mean decrease of 3.2 dB(A) between January 2012 and February 2012, due to the LTZ implementation. Nevertheless, an increase of 3.6 dB(A) between February 2012 and February 2013 occurred, bringing the noise levels back to the same values as January 2012. There might be several reasons for
this: a possible explanation could be a change of the noise sources composing the sonic environment. In urban contexts, indeed, it is likely that the ‘gap’ left by some noise sources (i.e. limitation of the traffic) will be ‘filled’ by different sources, due to changes of use of the space (e.g. more pedestrians, expansion of commercial activities on the street side).

Regarding the results of the social surveys, a ‘time’ effect was found to be statistically significant on both the assessment of the current sound environment and the perceived variation of the sound environment, with respect to the before-LTZ condition (January 2012). In general, the sample interviewed soon after the LTZ implementation reported overall positive opinions on the sonic environment and its variation, while the sample interviewed in 2013, reported more neutral opinions. The results from the analysis of the binaural recordings are somehow consistent with this trend. The differences between the ante LTZ and post LTZ condition were probably more evident to the interviewed participants in a short-term period. This finding is consistent with what had previously been observed by Bendtsen [28]; that is: on a medium-long term base people’s assessment of previous noisy environments grows in uncertainty.

According to the responses from the social surveys, ‘sound’ performed better over time, compared with other environmental aspects, both for the assessment of the current situation and for the perceived variations with respect to the ‘before LTZ implementation’ condition. For the latter circumstance, it is worth highlighting that a part of the sample keeps assessing a positive variation of the sound environment, despite of the noise levels being the same as before the LTZ implementation. This result claims for further consideration of behavioural and psychological effects that noise mitigation actions are likely to have on residents in urban areas.

In conclusion, the LTZ could be considered an effective strategy for the urban noise control and improvement of the environmental quality. On the other hand, it should be adequately actuated in order to preserve the achievements in terms of subjective perception by the local population.

Some limitations of this study consist of (1) the difference of groups interviewed for the social surveys during the two in situ campaigns, (2) the limited periods covered by the binaural recordings, due to the particular ‘dynamic’ acquisition methodology and (3) the focus of the study on a single city (i.e. the historic centre of Naples) that could have some context-dependent implications. For the future, it could be useful to consider focus groups of residents to perform long-term investigations on people’s change of attitude to the sonic environment and the built environment in general and extend this kind of survey to other test sites. From the planning viewpoint, this study suggests that future noise action plans should include some audit of people attitude to noise over time in order to monitor the effectiveness of the implemented measures.

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