

Assessment and mitigation of noise in urban areas: The case of the Alcântara neighborhood in Lisbon, Portugal

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ABSTRACT

The urban sound environment can be influenced by numerous fixed or mobile sound sources with temporary or permanent characteristics. The traffic noise is the most widespread and important noise source in urban areas. This hypothesis is supported by the results of sound level measurements and the assessment of induced annoyance due to road traffic noise, for the inhabitants of urban areas. In Lisbon, in the neighborhood of Alcântara, the road and rail traffic on the 25 de Abril Bridge is one of the most important noise sources, contributing thus for the deterioration of the sonic environment.

This paper presents a first approach on the evaluation and control of noise originated by the traffic on the 25th de Abril Bridge. Results of sound level measurements, and of the evaluation and processing of audio records, are presented. The envisaged objective is the identification of the acoustic signature associated to each relevant noise source (road, rail, and also air), considering the correlation between physical descriptors like the A-weighted equivalent continuous sound level and the psychoacoustic descriptors, ending up on the acoustics perception of the sonic environment. From the work done, some important conclusions are extracted.

Keywords: Noise, Environment, Annoyance

I-INCE Classification of Subject Number: 50

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1. INTRODUCTION

The Ponte 25 de Abril (25th of April Bridge) is a suspension bridge connecting the city of Lisbon to the city of Almada, located on the left (south) bank of the Tagus river, and has a total length of 2277.5 m. This bridge is composed by two overlapping platforms (see Figure 1). The upper platform has 14 sections and is intended for road traffic, with 6 traffic lanes (three in each direction), while the below platform is intended for rail traffic, with 2 traffic lanes (one in each direction).

In the north bank (Lisbon site) the access to the bridge is made by viaduct with 937 meters.



Figure 1 –View of the rail and road platforms of the 25 de Abril Bridge

In the rail platform (lower one) there are acrylic barriers (left photo of Figure 2), and sound absorbing barriers in the part of the access viaduct in the north bank (right photograph). Figure 3 shows a detail of the transition zone between the suspended bridge and the viaduct at the rail platform.



Figure 2 – Barriers installed at the rail platform



Figure 3 – Detail of the transition zone between the suspended bridge and the access viaduct

In the 25 de Abril Bridge surroundings, at Alcântara neighborhood, the soundscape is essentially dominated by the road and railway traffic noise. At the ground level, there is a large amount of roads, such as India and Brasília Avenues, and the Cascais Railway Line. Air traffic noise is another aspect that contributes to the degradation of the sound environment in this area. Effectively, the aircraft pathway of Lisbon Airport passes above this urban area, and the number of aircraft flying over has been increasing over the years. Sound warnings emitted by ships are also audible.

Regarding the road traffic noise from the 25 de Abril Bridge, it is characterized by a vibration humming caused by the passage of the vehicles over the metallic surface the lanes are composed by. At the ground level, near the north river bank and under the access viaduct, sounds with a very short duration are superposed to the humming mentioned above. This short duration sounds are related to the vehicles passing-by at the expansion joints of the road platform, being especially annoying for heavy traffic. As a result, the sound pressure levels established therein are relatively high, with an easily discernible tone, being distributed throughout the area, with some permanence.

The rail traffic noise, in particular in the transition zone between the suspended bridge and the access viaduct, is responsible for a loud and short duration sounds (but with a longer duration than that of the passage of vehicles over the joints of the road platform). As a result, the sound pressure levels established therein are relatively high, with an easily discernible loud tone, distributed throughout the area and with some permanence.

In terms of the overall sound qualitative assessment, the road traffic noise originated at 25 de Abril Bridge, contributes to a continuous signature of the soundscape in the surrounding area, while rail traffic noise contributes with acoustic events of a few seconds duration and clearly exceeding the continuous road traffic noise.

2. DATA COLLECTION

2.1 Sound levels measurements

Taking into account the complexity of the sound environment of the zone under study, it was decided to carry out sound levels measurements in places where the influence of residual noise is low, taking into account the traffic noise from 25 de Abril Bridge. For this purpose, 3 fixed places were selected, designated in this paper as: Pilar 7 (one of the pillar of the bridge); Carris Museum (named in this work as Museu da Carris), with two measuring points, Point 01 near the railway transition zone between the suspended bridge and the access viaduct and Point 02 located in the proximity of Pilar 7; and Miradouro Santo Amaro (a Viewing Point). This viewing Point is located at approximately 230 m distance from the pillar closest bridge, so that it is possible to have a broad view of the 25 de Abril Bridge, allowing the recording of sound levels from the circulation of traffic without obstacles in terms of sound propagation. Figure 4 shows the localization of the fixed sites selected. At Pilar 7, due to size restrictions of the equipment's power cables, the measuring equipment was located near the entrance door to the panoramic elevator. In this area, it is worth to notice the existence of reflecting surfaces of considerable dimensions, so that an increase in sound levels is expected due to potential reflections. It should be noted that the sound environment in this place is also greatly influenced by the road traffic in the India Avenue.

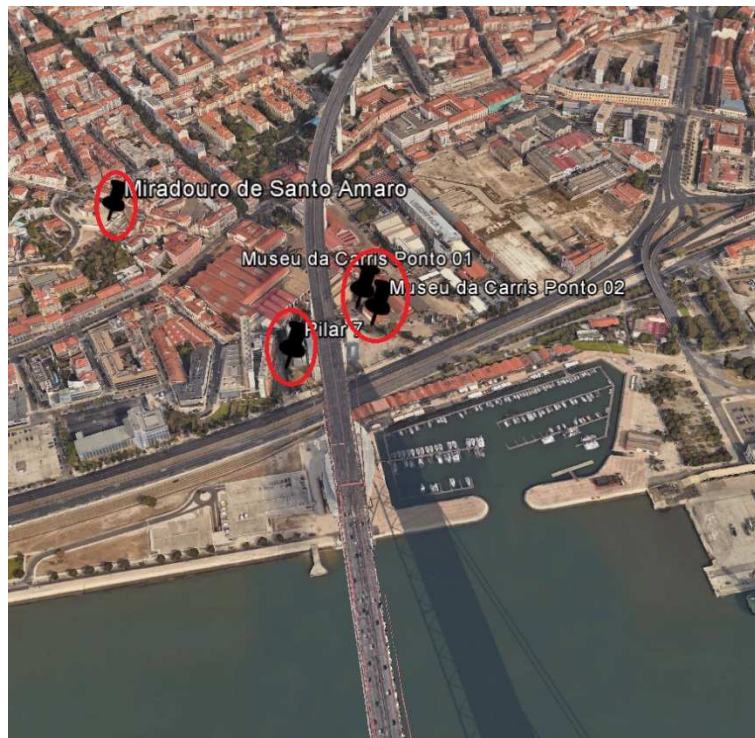


Figure 4 – Localization of fixed sound evaluation sites: Pilar 7; Museu da Carris (Carris Museum); and Miradouro de Santo Amaro (Viewing Point)

In all places, sound levels measurements with the real-time analyzer "Symphonie" from 01dB were carried out, lasting between 30 and 90 minutes, depending on the possible time of permanence in that place. Along with the temporal evolution of the sound levels, audio recordings were also collected, in order to allow for the identification of acoustic events, and register the correspondent frequency spectrum. In all cases, and because of the complexity of the surrounding sound environment, it was necessary to perform a data post-processing in order to identify the sources of sounds recorded; only taking into account the sounds coming from particular traffic noise sources of 25 de Abril Bridge. For this purpose, the dB_TRAIT software of 01 dB was used. For the 4 sites described, a questionnaire about the qualitative assessment of the sonic environment was filled up by the technicians involved in the assessments.

Table 1 presents the A-weighted equivalent continuous sound pressure level for the 25 de Abril Bridge traffic (road and rail), after post-processing the measurement results. Since in this area the sound environment is influence by the air pathway of the Lisbon airport, the number of aircrafts flying over and the corresponding A-weighted equivalent continuous sound pressure levels, are also shown.

In Table 2 a qualitative assessment of the sonic environment at the measurement sites is present. This assessment was made by the fulfillment of a questionnaire about the sounds presented in each measurement site, the frequency of occurrence of each sound, and a qualitative description of the measuring site using adjectives related with qualitative assessment and intensity of sound (like pleasant, noisy, annoying), and adjectives related with the temporal stability (monotonous) and with timbre (strident).

Table 1 – Synthesis of the measurements made: location, time of measurement, results and number of traffic passing-by

Site/ Distance to Bridge Axes	Measurement period	N° Train passing-by (both directions)	N° Planes passing-by	L _{Aeq} [dB(A)] (road and rail traffic on 25 de Abril Bridge)	L _{Aeq} [dB(A)] (road traffic on 25 de Abril Bridge)	L _{Aeq} [dB(A)] (rail traffic on 25 de Abril Bridge)	L _{Aeq} [dB(A)] (air traffic)
Pilar 7/ 20 m	11:03 h - 12:37 h	12	13	71	67	80	71
Museu Carris / 30 m							
Point 01	11:36 h - 13:07 h	18	14	66	63	73	70
Point 02	14:55 h – 16:34 h	14	22	68	63	76	70
Miradouro de Santo Amaro/ 230 m	15:20 h – 16:04 h	5	11	60	60	65	69

Table 2 – Synthesis of the qualitative assessment of the sonic environment at the measurements fixed sites

Site	Assessment time	Qualitative assessment of sonic environment
Pilar 7 23 m	10:10 h	The sound environment is characterized by a mixture of road traffic noise on India Avenue (light vehicles and buses), trains passing-by at Cascais Railway Line, road and rail traffic noise from the 25 de Abril Bridge, namely: passing vehicles over the metallic grid and over the joints in the access viaduct zone, also trains passing-by in the transition zone (Figure 3). In this place is also perfectly audible the airplanes flying over. Sporadically, sounds coming from ships are also audible. The most annoying sounds were associated with the vehicles passing-by on India Avenue and the trains passing-by on the bridge. The sound environment at this site was rated as noisy and annoying.
Museu da Carris	12:00 h (Point 01) 16:00 h (Point 02)	The sound environment is characterized by road and rail traffic noise from the 25 de Abril Bridge, namely: passing vehicles over the metallic grid and over the joints in the viaduct zone. In this place is also perfectly audible the airplanes flying over. Sporadically, sounds from trams are heard. The most annoying sound is from trains passing-by the transition zone (Figure 3). The sound environment at this site was rated as noisy and annoying
Miradouro de Santo Amaro 230 m	15:35 h	The sound environment is characterized by road and rail traffic noise from the 25 de Abril Bridge, namely: passing vehicles over the metallic grid and in the viaduct area and trains passing-by. In this place is also perfectly audible the airplanes flying over. The most annoying sounds are those from vehicles passing-by in the metallic grid and trains passing-by in the transition zone (Figure 3). The sound environment at this site was rated as monotonous.

In each fixed measurement site, a psychoacoustic characterization of the audio recordings taken was made. This characterization was made in terms of Loudness, Loudness 10%, Sharpness, Roughness, and Specific Loudness. For Pillar 7, the sound of vehicles passing-by over the metal grid. At Museu da Carris, for Point 01 audio samples from vehicles passing-by at the joints in the viaduct zone and audio samples from a train passing-by in the transition zone. At this site, for Point 02, a sample from the vehicles

passing-by over the metal grid was characterized. Finally, at Miradouro de Santo Amaro, samples from road and rail passing-by were characterized. Table 3 presents the results of this psychoacoustic characterization, including the most prominent critical bands. For each sound, the equivalent continuous and the A weighed sound levels are also presented.

Table 3 – Psychoacoustic characterization of sounds from 25 de Abril Bridge

Location	Source	Loudness sone	Loudness 10% sone	Sharpness acum	Roughness asper	Bark*	Leq dB	LAeq dB(A)
Pilar 7	Road Traffic	22,8	24,6	0,8	8,7	1,2,3	79	67
Museu Carris Point 01	Road Traffic	18,4	20,5	0,8	11,8	1,3	75	64
	Train Passing-by	35,9	43,8	0,8	9,8	2,4	76	66
Museu Carris Point 02	Road Traffic	18,7	20,1	0,8	11,9	1,3	84	74
Miradouro de Santo Amaro	Road Traffic	12,2	13	0,66	11,6	2,3,4	66	58
	Train passing-by	18	20	0,66	9,3	1; 3	73	61

2.2 Sound walks

This study also included the realization of two sound walks. The first sound walk, along the north bank of the River Tagus, started at Belém ferry terminal, going through Santo Amaro’s docks, and ending at Infante Santo Avenue. In this walk, short-term sound levels measurements were carried out and a qualitative description of the sonic environment was made. In this qualitative assessment, it was always noted whether the sound from the rail and road traffic noise coming from the 25 de Abril Bridge overlapped the sounds of nearby sources.



Figure 5 – Localization of sound levels measuring points at sound walk #1 along the north bank of the River Tagus

In Table 4, the results of the short-term sound levels measurements for sound walk #1 are shown. For each measuring point a description of the noise sources presented are also included.

Table 4 – Sort measurements and sonic environment description for sound walk #1

Site/ Distance to Bridge Axes	Measurement period	LAeq [dB(A)]	LA _F 95 [dB(A)]	Main noises sources presented
Local 01/ 1750 m	10:04 h -10:19 h (15 min)	67	54	Traffic noise from the 25 de Abril Bridge audible, overlapped with air traffic noise, noise from sightseeing buses, train noise from Cascais Railway Line, road traffic noise from Brasilia Avenue, and sounds from people walking.
Local 2/ 970 m	10:40 h -10:55 h (15 min)	63	60	Road traffic noise from the 25 de Abril Bridge is perfectly audible, with a permanent character, air traffic noise and the train noise from Cascais Railway Line.
Local 3/ 0 m	11:11 h -11:26 h (15 min)	79	73	Traffic on the 25 de Abril Bridge:(vehicles passing over the metallic grid of the bridge platform and trains passing-by.
Local 04/ 602 m	15:16 h -15:31 h (15 min)	64	56	Traffic from the 25 de Abril Bridge (vehicles passing over the bridge metal grid and trains passing-by), and noise of airplanes passing over.
Local 05/ 1030 m	16:15 h -16:30 h (15 min)	63	58	Traffic from the 25de Abril Bridge (mainly due to the passage of vehicles on the metallic grid), sound of the passage of airplanes passing over (6) and trains of the Cascais Railway Line (2).
Local 06/ 1600 m	15:49 h -16:04 h (15 min)	69	60	Traffic noise from the 25de Abril Bridge (mainly due to the vehicles passing over the bridge metallic grid), masked by traffic noise on 24 de Julho Avenue, airplanes passing over (4) and trains from Cascais Railway Line (2).

The second sound walk #2 started at Rua da Junqueira, in front of Egas Moniz Hospital (number 126), and ended at Largo do Calvário, going through 1^a de Maio Street (Figure 5). At select places along this walk, questionnaires of qualitative assessment of sound environment were filled up, after a stay of 10 minute duration in each place.



Figure 5 – Localization of qualitative sound environmental assessment points in sound walk #2 (Junqueira Street to Largo do Calvário)

Table 4 – Synthesis of the qualitative assessment of sound walk #2

Site/ Distance to Bridge Axes	Assessment time	Qualitative assessment of sonic environment
Hospital Egas Moniz (Junqueira Street 126) 760 m	9:55 h	The sound environment is characterized by the road traffic noise at Junqueira Street (light vehicles, buses and trams), air traffic noise and train noise from Cascais Railway Line. At this location, traffic noise from the 25 de Abril Bridge is not audible. The most annoying sounds are those associated with bus passing-by, followed by the train noise from Cascais Railway Line. The sound environment at this location was rated as strident and annoying.
Instituto de Higiene e Medicina Tropical (Junqueira Street 100) 600 m	10:15 h	The sound environment is characterized by the road traffic noise at Junqueira Street (light vehicles, buses and trams), and air traffic noise. In this site traffic noise from 25 de Abril Bridge is not audible. The most annoying sounds are those associated with aircraft taking off and landing. The most annoying sounds are those associated with airplanes, followed by bus and tram passing-by. The sound environment at this location was rated as noisy and annoying.
Junqueira Street nº 1 165 m	14:20 h	The sound environment is characterized by a mixing of road traffic noise from Junqueira Street (light vehicles, trams and buses) and traffic from 25 de Abril Bridge, namely: trains and road vehicles passing-by, with noticeable events related with vehicles passing over the metallic grid. It is also perfectly audible the airplanes flying over, as well as the passage of trains on the Cascais Railway Line. The most annoying sounds are those associated with trains (Cascais Line) and traffic passing-by on the 25 de Abril Bridge. The sound environment at this site was rated as noisy, annoying and monotonous.
1 de Maio Street, nº 112 15 m	15:00 h	The sound environment is characterized by the road traffic noise at Junqueira Street (light vehicles, buses and trams), and trains passing-by on the 25 de Abril Bridge. It is also perfectly audible the airplanes flying over. The most annoying sounds were those associated with bus passing-by, followed by airplanes. The sound environment at this site was rated as chaotic, noisy and annoying.
1 ° de Maio Street, nº 19 (next to Largo do Calvário) 125 m	16:20 h	The sound environment is characterized by the road traffic at Junqueira Street (light vehicles, buses and trams). At this site the trams passing-by on 25 de Abril Bridge are audible. It is also perfectly audible the airplanes flying over. The most annoying sounds were those associated with airplanes and busses passing-by. The sound environment at this location was rated as noisy, annoying and strident.

4. CONCLUSIONS

This study presents a preliminary and spatial identification of the noise sources associated with traffic on 25 de Abril Bridge, and the corresponding sensitivity of their created soundscapes at ground level.

In this context, an inventory and consultation of the existing documentation of the area under study, namely the Noise Maps and Action Plans of the 25 de Abril Bridge and of the city of Lisbon and Portela Airport (Lisbon Airport) were carried out. In the same way an inventory of possible complaints and their geographic location, allowing a perspective of the various interrelationships between the various instruments for noise management and control in the area, as well as the relevance analysis of the effects of the sound source 25 of Abril Bridge to the global environment, were also done.

With the information provided by National Road Administration (Infraestruturas de Portugal), it was possible to process the traffic data of 25 de Abril Bridge, and thus to select the most appropriate measurement methodologies for each sound source that is originated at 25 of Abril Bridge (road and rail).

Finally, short-term measurements were carried out at previously selected sites in order to identify the preferred reference sites for future measurement campaigns, and where the

influence of ground level traffic on the area being evaluated is, or can be, reduced. These measurements also allowed to identify the sound signatures of the sources under evaluation, as they were accompanied by simultaneous recording of audio signals. Simultaneously, sound tracks were performed enabling a first approximation of noise in the area under study, thus allowing the possible evaluation options to be considered in future analyzes.

On the basis of these work and respective results it is concluded that 25 de Abril Bridge contributes mainly with 2 types of sound signatures into the neighboring surroundings. One type of sound is related with the vibration humming caused by the passage of the vehicles over the metallic surface, and the second is related with the passage of trains, especially at the transition zone between the suspended bridge and the access viaduct. These sounds are audible in a far distance, for more than 1000 meters, as it could be rated in sound walk #1. Unfortunately, the city sounds at Alcântara area are not so quiet, being able to mask the sounds from the Bridge, as it could be rated in sound walk#2, up to a distance of about 200 meters from the Bridge, and at daytime.

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