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Research Article

Evaluation of the Sound Quality at Bardo's Urban Park: Pollution or Ambiance?

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ABSTRACT

Urban parks are increasingly recognized not only as recreational and ecological assets but also as critical spaces for acoustic comfort in densely populated cities. This study investigates the sound environment of the Bardo Urban Park in Constantine, Algeria, an important urban project with a unique spatial configuration and significant public use. The research adopts an *in situ* approach to assess the park's soundscape, focusing on both quantitative and qualitative dimensions of acoustic comfort. A three-phase methodology was employed: first, a sound map was generated using Olive Tree Lab Suite software; second, field measurements were taken at focal axial points across the park using a calibrated sound level meter; third, a comparative analysis was conducted between simulated and measured data to construct a comprehensive acoustic profile of the site.

The results reveal spatial heterogeneity in sound levels, with high noise zones primarily located near human activity centers and commercial areas, while quieter zones are found in vegetated or peripheral regions. Traffic, speech, and natural sounds such as river flow were identified as major acoustic contributors. Notably, peak sound levels exceeded international comfort thresholds in several zones, particularly during high-attendance periods. Based on the findings, the study proposes several recommendations to enhance acoustic comfort, including strategic land use planning, implementation of vegetative and structural noise barriers, and visitor traffic management through spatial zoning and timed access strategies.

This research contributes to the emerging discourse on soundscapes and acoustic urbanism by offering a replicable framework for evaluating and improving sound quality in urban parks, reinforcing the importance of sound ambiance as a determinant of urban environmental quality.

Keywords: soundscape, acoustic comfort, sound mapping, noise pollution Bardo Park, Constantine.

Introduction

Urban attractions are the vibrant heart of any major city in modern days, the life quality in those places can generate a large difference in the overall experience and perception of the city from both its

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inhabitants or its visitors, for example, in urban parks, many elements could effect on the life quality of the space such as vegetation, clean air, cleanness, safety and silence (Carvalho & Cleto, 2012) therefore, the sound environment is one of the major indicators of a quality of life (Léobon, 1995)

Urban parks can function as a proper sink of noise pollution, however, lack of universally agreed upon methodologies and differing urban conditions have fueled controversy surrounding the effectuation of this urban park function around the world. (Tashakkor et al. 2020)

In a policy of reducing the annoyance linked to noise pollution, techniques, which quantitatively correct the sound level no longer, seem to be sufficient; new concepts are introduced such as those of “ambiences” or sound “landscapes” which require taking into account the qualitative aspects of acoustic phenomena. (Carvalho & Cleto, 2012)

In a world where each urban attraction has its own sound environment and the information received by the ear in our apprehension of space is as rich as that collected by the eye (Schaeffer,1979) the utopia of silence is replaced by a more realistic approach: THE SOUND AMBIANCE (Augoyard. 2000), the sound is always present, it accompanies visitors from their arrival in the urban park to their departure, passing through the attractions, shops and other common areas giving space a certain vibe and identity (Augoyard. 2000)

In urban parks, visitors in most of the time occupy a large space; therefore, it is important that the sound level and quality are uniform to a certain level and the visitors are never exposed to a level of decibels causing acoustic discomfort by international standards.

Litirature Review

Before the 1970s, research in acoustics and psycho-acoustics only approached urban space and daily life through a few applications emanating from musical acoustics, room acoustics, audiology and phonology, nevertheless, since the 1970s, researches on noise have approached the urban entity but in a fragmentary way: through physical elements (vibrations, noise from transport, construction sites), health (regulations of nuisances affecting buildings and roads) or economic (social and land cost of noise). (Augoyard. 2000)

Urban noise pollution has become a pressing issue in Algerian cities, where sound levels, particularly from road traffic, often exceed regulatory thresholds and significantly impact public health and well-being. For instance, residential areas report levels as high as 74 dB (Boulemaredj & Amel, 2023), while cities like Biskra record ranges from 55.3 dB to 75.8 dB on weekdays, frequently surpassing permissible limits and reducing quality of life (Bouzir et al., 2017).

This growing concern is attributed to increased population density, vehicular traffic, and poor urban planning, particularly in urban centers such as Guelma (Boulemaredj & Haridi, 2022). Studies show that prolonged exposure to excessive noise is associated with cardiovascular diseases, hearing loss (Shirzad et al., 2022), and psychological conditions such as stress, anxiety (Paneto et al., 2017), depression, insomnia, and reduced cognitive performance (Sneha et al., 2024). In light of these health implications, urban sound management is gaining importance.

Mujawar (2025) introduces innovative tools such as real-time road traffic auralization and machine learning-based sound classification, which offer more accurate representations of noise and support better-informed urban planning. The use of low-height noise barriers and green infrastructure, including plants and natural elements, not only mitigates noise levels but also enhances the aesthetic and ecological quality of urban spaces (Mujawar, 2025; Paneto et al., 2017).

Empirical studies conducted in Algeria further emphasize the need for such strategies. For example, research in Didouche Mourad Street, Constantine, during the COVID-19 pandemic demonstrated changes in urban soundscapes and public perception, revealing the adaptability of urban environments to disruptions (Bensaada et al., 2024).

Similarly, noise assessments at the University of Adrar highlight how desert climates amplify noise challenges and stress the importance of contextualized mitigation approaches (Arbaoui et al., 2024). Holistic planning, including noise zoning and the use of sound-absorbing materials, is thus essential to counteract the effects of urbanization and to foster healthier, more livable cities ("Synergizing Design and Engineering", 2023).

Study Area

The selection of urban park of Bardo in this study was based on its placement and significance within the city of Constantine including its importance impact as an urban project with a major role in the restructured image of the city, this park is considered to be an experimental field with a special spatial

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pattern of homogenous surface where the sound environment is sufficiently diverse for an acoustic evaluation.

the Bardo's urban park has become the area of attraction most frequented by the inhabitants of the city of Constantine, with a total area of 41 hectares in the city center, this park is an exceptional outdoor site located on the banks of the Rhumel below a crossing of the two most imposing bridges in the city: The Sidi Rached bridge and the Trans-Rhumel viaduct.

Opened to the public on July 5th 2022, The park is intensely visited especially in weekends with an average of one hundred families (according to the park administration), However, the work remaining to be carried out, in particular the placement of the Ferris wheel, the completion of the swimming pool still under construction, all that could be considered as potential sound sources.

The initial question in our study was:

"Is there a noise pollution at the Bardo's urban park?"

Noise pollution is a public health problem, a source of physical and psychological tension, it also disrupts the functioning of fauna, insects, birds and flora, it creates urban nuisance.

That question led us to the silence notion in urban park: "*Silence can only be found if we choose sobriety, by adopting a lifestyle that consumes less energy and mechanics*" (Dutilleux, 2012) but this is also not the case in the park of Bardo where mechanic roads interfere in the conception of the park from beginning to end.

Primary issues are studied in this paper; we perform a nonlinear modeling and analysis, controllers design, and a comparative of the obtained field measurements with the theoretical results.

Finally, we landed on the most appropriate question to tackle this issue: What is the sound quality in Bardo's urban park? Is it a sound ambiance? Or is there acoustic pollution or nuisances interfering with sound environment and transferring it to less pleasurable space? If so, is a sound reproduction system will be necessary? Choosing for sure a natural reproduction scenario, a reproduction as close as possible to reality.

Our approach is "in situ' (Augoyard,1995): a "test of the in situ" is a more general and global approach to evaluating sound in open spaces, an interdisciplinary in theories approach which involves epistemological changes and has provoked a progressive consideration of the sound environment as a global phenomenon.

The objectives of this work are the analysis of the sound quality, in other terms, analysing the acoustic characterization of the park starting by identifying the acoustic sources based on Schafer's classification traffic, human sounds, music…etc. (1979)

We started by inserting the park's map and those source into the olive tree lab suite software which has produce for us the noise map of the park, then, we took some filed measurements based on the focal axial points of the park, finally, after obtaining the field measurements we conducted a juxtaposition analysis using the generated map and the field measurements for a general sound map of the Bardo's park.

The morphology of the park is very special, designed to respect the topography of the site, it was divided into platforms joined by scales, pedestrian paths and mechanical roads with low traffic and speed limit of 30km/h, those platforms contains play areas, relaxation areas with urban furniture, the environment direction and several commercial stands and shops (figure 1), the vegetation is composed of fragments of small-medium sized native trees with maximum average height of 12 m, as well as ornamental species, with two building and some wood construction.

Data and Methods

The main goal of this work is to study the soundscape of Bardo's urban park, the most significant city urban park of Constantine, the third largest town in Algeria with 448 374 inhabitants (RGPH,2008) and 231.6 km² using an exploratory method to decide on the quality of sound in the park, it was divided into three steps:

- 1st step: drawing a sound map that allows us to evaluate the sounds in the environments in the park using the software olive tree lab suite,
- 2nd step: taking the field measurements in focal axial points using sonometer Amprobe (SM-10 of 8 kHz) , this is a longitudinal study in reference to taking measurements in two different frames times (weekend/ week days) during a whole week, also a qualitative and applied study that will generate recommendation based on its results.

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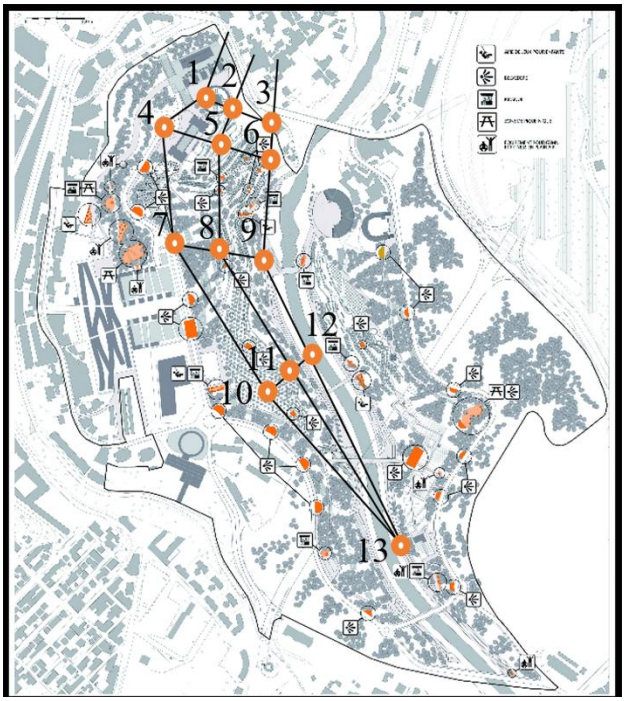

Figure 1. The chosen points of the field measurements.

The following procedures were followed for the in-situ measurements:

- Meteorological conditions were taken into account not using rainy days or when the wind speed was above 5 m/s.
- A time schedule was used in this study between 3pm and 6pm in the week days and between 10am to 7pm in weekends because it is the most crowded time of the day for both periods (the park closes in the night).
- To choose the measuring positions within the park we divided the park into platforms and noise sources then we choose the focal axial points as the points of field measurements.
- Each measurement position was chosen not to interfere directly with the visitors and at least 3.5 m from any reflective surface.
- The sound level meter was placed in each position at a height of 1.2 to 1.5 m.

➢ 3rd step: juxtaposition of the results using olive tree lab suite which we were granted authorization to use and proposing a natural reproduction of a sound map.

In our study we used two materials:
1/ Olive tree lab suite: it is a 3D acoustical software applications integrated in one working environment, the PEMARD institution has given as the license to use it.
2/ SONOMETRE testo 816-1 offers measurements that ranges of 30 dB to 130 dB.

Results

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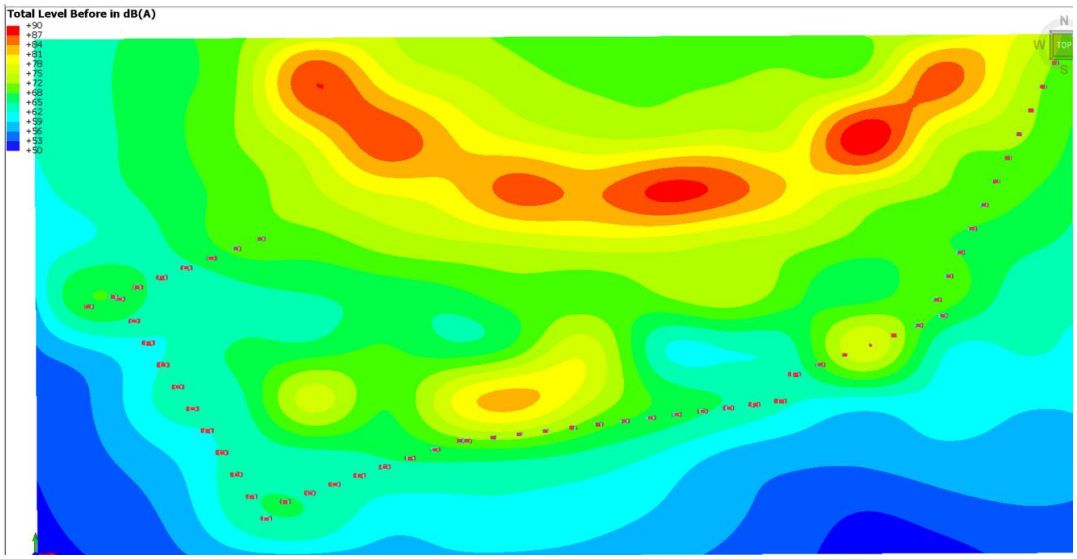

Figure 2. The sound map generated by Olive Tree Lab Suite.

Figure 2 represents a sound map that visualizes the distribution of noise levels across the urban park of Bardo Constantine, different colors are used to indicate varying noise intensities:

- Red and orange zones represent high noise levels.
- Green and blue zones indicate quieter areas.
- Red Zones (High Noise): The red zones on the map correspond to areas where noise intensity is elevated.
- Small red crosses: These represent measurement points or sources of sound within the mapped area.
- The vertical color scale bar on the left side corresponds to different decibel levels in dBA (A-weighted decibels).

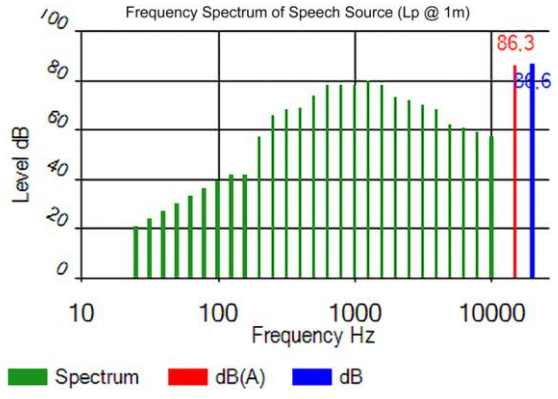

Figure 3. The speech analysis results of Olive Tree Lab Suite

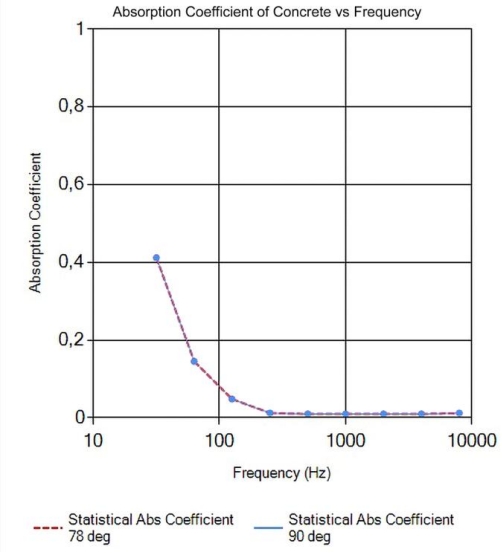

Figure 4. The absorption of materials of Olive Tree Lab Suite

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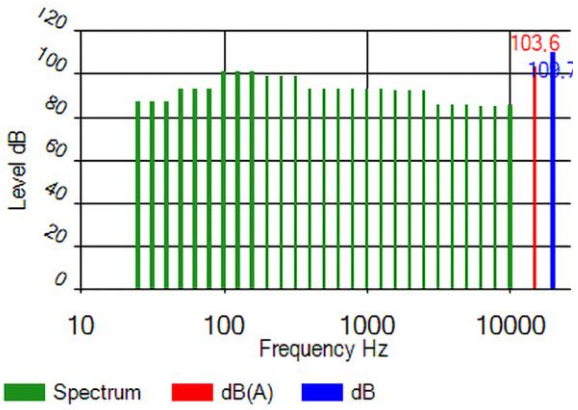

Figure 5. The river sound analysis results of Olive Tree Lab Suite

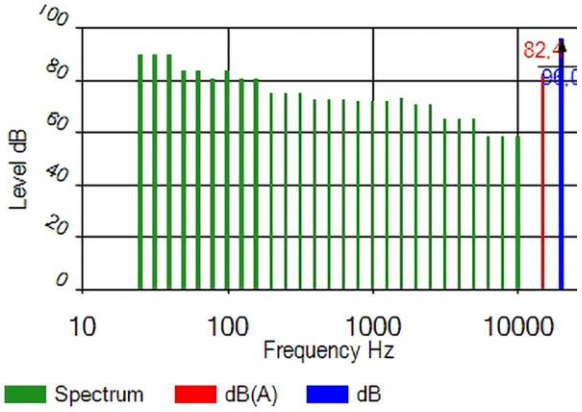

Figure 6. The traffic analysis results of Olive Tree Lab Suite

The graphs displays the sound levels in dB and dB(A) across various frequencies measured in Hertz (Hz).
The x-axis represents the frequency, ranging from approximately 10 Hz to over 10,000 Hz.
The y-axis shows the sound levels:
The blue line represents the sound level in dB (decibels).
The red line corresponds to the sound level in dB(A) (A-weighted decibels).
We will be discussing sounds by sources then the overall results after the juxtaposition of the stimulation with the field measurements:

- Traffic Noise:
  The sound generated by road traffic (figure 6) considered factors such as vehicle speed, type of vehicles (cars, trucks, motorcycles), and the average number of vehicles passing through a road section.
  The simulation allowed us to experience real-time traffic noise, which was considered average to low because only service cars are allowed into the urban park.
- Speech Noise:
  In figure 3 we identified areas where children play, these zones will contribute to the overall acoustic environment.
  The simulation considered the intensity and frequency of the activities, affecting the noise levels in different parts of the park, the noise was found average to high because it is proportional with the attendance especially from children.
- River Noise (Oued Rhumel):
  Oued Rhumel, being a river, may contribute ambient noise due to flowing water, birds, and other natural elements.
  We incorporated this natural soundscape into the simulation, considering its impact on the overall acoustic environment as shown in figure 5, it exhibits consistent average to high sound levels across various frequencies because its regular flow.

Table 1. The results of the field measurements.

	Date	Attendance	Weather	dB
P1	**04/05/2024**	**High**	**windy, Dry, Average temperature 25°**	**71**
P2	**04/05/2024**	**High**		**73**
P3	**04/05/2024**	**Average**		**64**
P4	**04/05/2024**	**Low**		**57**
P5	**06/05/2024**	**Average**	**Clear sky, dry, average temperature 27°**	**67**
P6	**06/05/2024**	**Low**		**53**

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P7	**06/05/2024**	**High**		**80**
P8	**06/05/2024**	**High**		**81**
P9	**09/05/2024**	**Low**	**Sunny, dry, average temperature 30°**	**52**
P10	**09/05/2024**	**High**		**79**
P11	**09/05/2024**	**High**		**73**
P12	**11/05/2024**	**Average**	**Cloudy, rainy, average temperature 25°**	**61**
P13	**11/05/2024**	**Average**		**54**

Discussion

The Sound Map Analysis:

We notice that the high sound is concentrated in the south and the south right portions of the park, these zones correspond to the river and the high human activity areas (commercial areas).
Moderate Noise Areas (Yellow/Green) are found in the middle of the map, surrounding the high-noise zones, this indicate transitional zones or paths with moderate foot traffic or nearby but less intense noise sources.

Low Noise Areas (Blue/Cyan) are found in the north portion of the park except the middle (small commercial areas), these represent quieter zones, dedicated to relaxation.

Juxtaposition of the field measurements with the stimulated sound map:
High Noise Zones correlate strongly with locations P7, P8 and P10, these points are in areas with high attendance because it's found near the main road, the commercial area, open spaces with crowds especially children.

Moderate Noise Zones match with P1–P3, P5, P11, P12, effect areas with consistent park use but not major crowd density, the moderated noise is due to the river or the non-regular attendance in sunny days.

Low Noise Zones match points like P4, P6, P9, and P13, these zones are quieter, secluded paths or vegetated zones with lower human activity.

Recommendations for Enhancing Acoustic Comfort in the urban park of Bardo based on the results:

- Integration of Noise-Sensitive in future Land Use Planning: Given the urban context and cultural significance of the Bardo Park, it is essential to integrate noise-sensitive land use planning into its management. Buffer zones or transition areas should be established between high-activity zones and sensitive areas to reduce the impact of ambient noise.
- Implementation of Physical Noise Barriers and Vegetative Buffers: the use of natural and constructed sound barriers can be strategically employed within Bardo Park. Dense vegetation can serve as effective buffers against urban noise, particularly along the river and park's perimeters facing major roads, acoustic barriers may also be introduced to shield particularly noise-sensitive zones in the future planning.
- Improvement of absorbent surfaces and floor coverings: The use of permeable and absorbent materials for paths (gravel, wood chips, porous pavers) can reduce the noise of steps and rolling equipment (strollers, bikes, etc.). This also limits the reverberation of sound on hard surfaces.
- Regulation of Visitor Movement through Traffic Control and Zoning: visitor management is essential in maintaining acoustic comfort, especially during weekends, holidays, and cultural events when attendance peaks. Implementing spatial zoning within the park—distinguishing between high-activity and quiet zones—can help balance usage. Moreover, regulating group sizes, introducing staggered access hours, or designating one-way walking paths may reduce the intensity and concentration of noise in key areas.

Conclusion

The study of the sound environment in Bardo Urban Park reveals a complex and dynamic acoustic landscape shaped by a combination of natural elements, human activity, and infrastructural design. Through a methodological framework combining simulation, field measurement, and spatial analysis, the research has demonstrated the presence of both beneficial and problematic acoustic zones within the park.

Areas with high attendance and commercial activity, particularly those near mechanical roads and open plazas, exhibited elevated noise levels, at times exceeding internationally recognized thresholds for acoustic comfort. In contrast, quieter zones were predominantly located in the park's vegetated and peripheral regions, offering opportunities for rest and relaxation.

These findings underscore the need for integrated acoustic planning in urban parks, particularly in contexts like Bardo, where recreational, ecological, and urban functions intersect.

The presence of diverse sound sources—ranging from river flow and bird calls to traffic and children's play—highlights the importance of managing not only the intensity of sounds but also their spatial and temporal distribution.

The proposed recommendations, including vegetative sound buffers, strategic zoning, traffic regulation, and weather-responsive management, aim to enhance the overall acoustic ambiance and user experience.

Ultimately, this research reinforces the value of considering sound as an essential dimension of urban space planning. By adopting a more holistic and qualitative approach to noise management, urban parks such as Bardo can evolve into acoustically comfortable environments that support well-being, biodiversity, and cultural identity.

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