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Assessing Soundscape and Urban Noise Pollution: A Case Study of Liberty Square (Church Square) in Skikda, Algeria

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ABSTRACT

The Liberty Square in Skikda is a central urban space characterized by heavy traffic (more than 283 cars per 15 minutes on Av Didouche Mourad, next to the Liberty Square, during peak hours) and social activity. This situation generates noise pollution that can affect users' comfort and detract from the heritage environment. In this context, the present study aims to characterize the square's soundscape using an approach that combines in situ measurements and digital modeling. Acoustic surveys were conducted using a sound level meter at several strategic points within the square, allowing sound pressure levels to be measured in dB(A). These measurements were then compared with the results of a simulation conducted with Olive Tree Lab software, yielding a detailed sound map. The analysis reveals that the highest levels (up to 80 dB(A)) and above are concentrated along the road axes, confirming the dominant role of motor traffic as a source of nuisance. The central area, on the other hand, has moderate levels due to sound dispersion, which is favored by the square's openness. The study concludes that mitigation measures are necessary, including the integration of green barriers, the creation of pedestrian areas, and the reorganization of traffic flows, to improve the sound quality and quality of life in this iconic space.

Keywords: Soundscape; Noise evaluation; Noise pollution; urban park; Skikda.

INTRODUCTION

In the context of rapid urbanization and the increasing densification of public spaces, the issue of urban sound quality has become a major public health and planning challenge. (Kang, 2013), (Bouzir T. A., 2022) Urban noise pollution has emerged as one of the most pressing environmental concerns in modern cities, driven by the rapid expansion and development of urban areas worldwide. (Jiang,2023) Urban acoustics, as an interdisciplinary field, focuses on the study of sound behaviour in built environments, incorporating aspects related to acoustic propagation, urban morphology, and sound perception by users (Kang, 2013), (Bouzir T. A., 2022). Its focus is not limited to noise reduction; it also aims to improve soundscapes, i.e., the quality of the perceived acoustic environment, to promote collective well-being (Luzzi, 2017).

Public squares are among the areas most exposed to noise pollution, as they serve as convergence points for multiple sources of noise, including road traffic, social activities, and reverberating street furniture. In several cities, noise levels regularly exceed legal limits, which hurts the physical and mental health of those who use these spaces (Paneto, 2017), In Algeria, in-situ measurements have revealed sound levels of up to 75 dB in some urban regions, particularly in Biskra and Guelma. These levels are significantly higher than those recommended by the WHO, (Bouzir T. A., 2017), (Boulemaredj, 2023).

Managing noise pollution requires an in-depth knowledge of urban configurations and local social dynamics. The way sound propagates, reverberates, or is absorbed is influenced by the morphology of spaces, the height of buildings, the openness of roads, and even the type of road surface (Alonso Montolio, 2019); (Jain, 2018). At the same time, the emergence of acoustic surveillance technologies, intelligent mapping, and artificial intelligence is opening up new

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possibilities for analysing, anticipating, and mitigating noise pollution in public spaces (Alías, 2019), (Liu, 2024) (Razavi-Termeh, 2024).

The analysis of urban acoustic environments has long been dominated by quantitative approaches based on sound pressure levels (LAeq). These approaches have not accounted for the diversity of sound sources or their varying contextual impacts. However, recent studies have emphasised the need for a more systemic and qualitative approach that integrates psychoacoustic, eco-acoustic, and cultural dimensions (Gopal, 2016) ; (Bouzir T. A., 2022).

Several studies have demonstrated the significant influence of street and building configurations on sound propagation. For example, urban canyons formed by narrow streets bordered by tall buildings can increase sound reflections and intensities in neighboring residential areas (Montolio & Cabillo, 2019). Similarly, the geometry of building façades plays a crucial role, and rigorous geometric analysis can predict their effect on sound diffusion and reflection. This approach facilitates integrated acoustic design (Tokaç et al., 2024).

In recent years, soundscape analysis has relied on a range of tools, including geographic information systems (GIS), acoustic cameras, and ray-tracing algorithms. This approach has been successfully employed in Pasaia, Spain, where urban improvement proposals have been developed based on detailed acoustic analyses (Bort et al., 2023; Benameur et al., 2021). This multi-tool approach is particularly relevant for public spaces, where the variety of sources and uses makes analysis complex and nuanced.

Furthermore, advances in artificial intelligence are providing new solutions, such as automatic classification of noise sources, dynamic, real-time noise mapping, and simulation of sound-masking or vegetation-management scenarios (Alías et al, 2019; Lam et al., 2024). These technologies have the potential to transform traditional noise management strategies into practical decision-making tools for urban planners, promoting participatory and context-sensitive planning (Hemmat et al., 2023; Jain et al., 2018).

This study employs a quantitative and spatial approach. Base with an experimental study validated with a simulation study. Then, we use the Olive tree software to validate the experimental study and develop the proposed solution. The acoustic data collected was then processed using the Olive software, enabling the analysis and interpretation of the recorded noise levels (in dB). In a second stage, the results were integrated into a Geographic Information System (Inverse Distance Weighting (IDW) interpolation). This approach enabled the spatialization of measured noise levels and the production of a thematic noise map, highlighting the areas most exposed to noise pollution within the square.

Fieldwork involved measuring noise levels at several points (P1 to P30) within the square. The points have been chosen using a non-regular grid.The points have been preferentially located around the square along traffic roads and along pathways mostly used by square visitors. All measurements were carried out on working days (Monday 10/06/2023), under ideal meteorological conditions: a sunny day, no wind or rain, and between 10 and 12 a.m. This time of day marks the peak in visitor numbers, high urban activity, and the highest traffic intensity on the roads surrounding the square. The duration of each measurement was of 4min. Each point was measured for the equivalent noise level (Leq) using a calibrated type 2 sound level meter. GPS coordinates and environmental observations (traffic, crowds, wind, etc.) were recorded. These points are shown on the map (Figure 2.C) the coordinates of the measurement points are given in Table 2. The results of the measurements are compared with the Limits of outdoor ambient noise set by the World Health Organization (WHO, 1999) and the thresholds of ISO 1996 standards (Table III).

outdoor ambient noise set by the World Health Organization (WHO, 1999):

50 moderate annoyance, daytime and evening.

55 serious annoyance, daytime and evening.

The measured levels were grouped according to the thresholds of ISO 1996 standards

- 55–60 dB: acoustic comfort zone
- 61–70 dB: moderately noisy zone
- 71–80 dB: noisy zone

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- 80 dB: very noisy/harmful zone

STUDY AREA

The study area is The Liberty Square, located in a historic coastal city in Algeria. The city chosen is Skikda, with about 202,567 inhabitants, and 55.44 km2 of area, located in north-eastern Algeria (36° 52' 00'' N and 6°54' 00'' E) (Leulmi, 2023), approximately 500km from the capital Algiers. (Figure 2-a)

Skikda is known in Algeria as an important administrative, industrial, tourist, and economic pole and features a high population density (more than 4004 persons/km2). (Lantada, N.2018.)

A HISTORICAL OVERVIEW OF THE STUDY AREA

The city of Skikda, formerly Philippeville, is a prime example of colonial urban planning in Algeria.
Liberty Square was first created as a large square in the 1840s on the site of the former Roman Forum of the Capitoline Hill. It features a public well. During the 1850s and 1860s, a statue of Antoninus Pius and the Church of the Sacred Heart of Mary were added, after which the square was renamed Church Square. At the beginning of the 20th century, the square was transformed into a beautiful esplanade lined with palm trees and overlooking the station and the port. It featured ponds, a statue of Brennus (later moved), and a fountain. At the time, it was known as Place Carnot. (Lallemand, 1895), It then housed a war memorial until 1969. Finally, in the 1970s, the southern half of this popular central location was demolished to make way for Liberty Square, complete with kiosks and cafeterias.

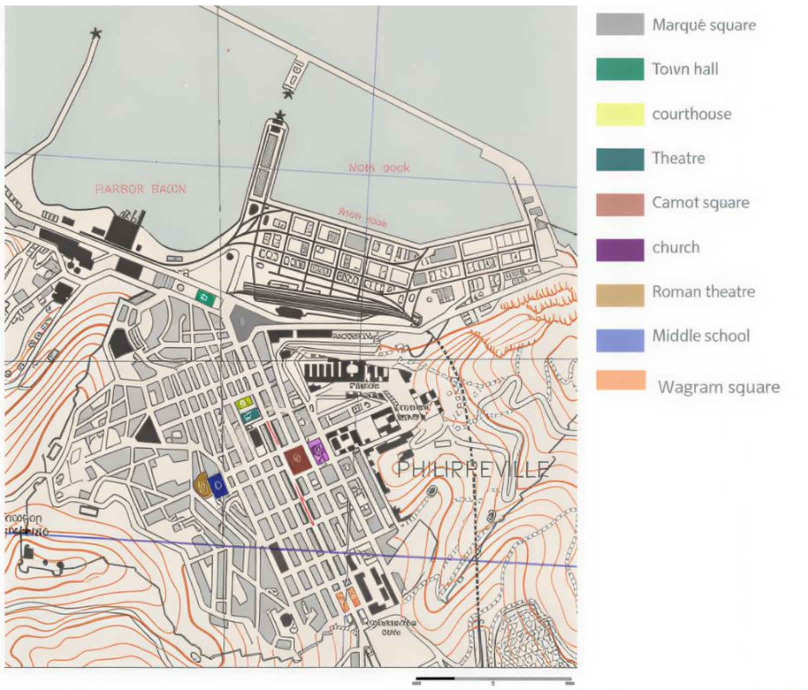

Figure 1. Historical map of Skikda (1942),

Characteristics of the Study area

Liberty Square, with its urban character, features a diverse array of small to medium-sized trees with an average maximum height of 15 meters, most of which are evergreen, making them a suitable choice for public parks (Table 1), as well as ornamental plant species. The park is a tourist destination and an important part of local residents' daily lives. The following table illustrates species found in The Liberty Square:

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Table 1: List of Vegetal species found in Liberty Square.

Scientific name	Common name
Salix babylonica	Weeping willow
Morus	The mulberry tree
Melia azedarach	Neem tree
Ficus	Ficus
Shinus molle L	False pepper tree
Cupressus semperviren‍t	Cypress evergreen
Biota orientalis	Biota
Palmier Washingtonia	Palm tree
Ligustrum	privet
Eucaluptus	Eucalyptus globulus/gum tree
Gliditsia triacanthos L	American hackberry
Celtis australis L	Provence hackberry

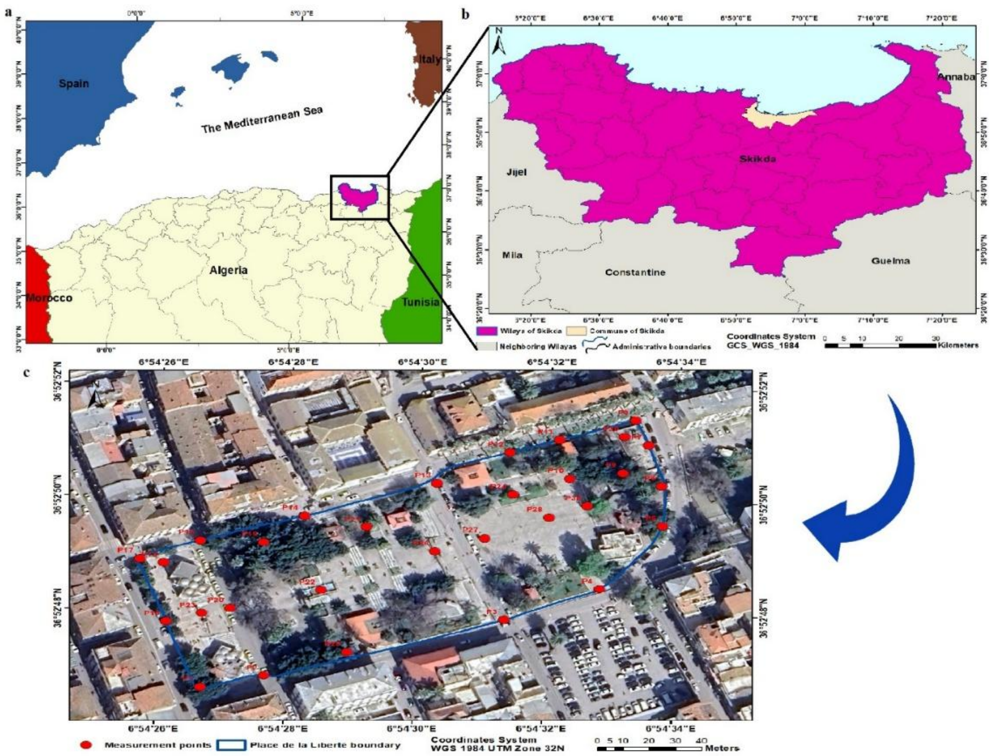

Figure 2. a. Location of the city of Skikda in Algeria in relation to the capital Algiers. b Location of the city of Skikda in the province of Skikda. c Overview on the location of the study area (Liberty Square).

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Table 2: points Measurement coordinates

points	Measurement coordinates		points	Measurement coordinates	
	Coordinates X	Coordinates Y		Coordinates X	Coordinates Y
P1	36°52'47.35"N	6°54'28.04"E	P16	36°52'49.42"N	6°54'27.25"E
P2	36°52'47.44"N	6°54'28.96"E	P17	36°52'49.52"N	6°54'27.04"E
P3	36°52'42.48"N	6°54'31.22"E	P18	36°52'48.98" N	6°54'27.55"E
P4	36°52'48.08" N	6°54'32.85"E	P19	36°52'49.22"N	6°54'27.77"E
P5	36°52'51.24"N	6°54'34.78"E	P20	36°52'48.25"N	6°54'28.37"E
P6	36°52'50.62"N	6°54'34.16"E	P21	36°52'49.24"N	6°54'29.74"E
P7	36°52'51.93"N	6°54'32.61"E	P22	36°52'50.72"N	6°54'30.51"E
P8	36°52'51.95"N	6°54'32.64"E	P23	36°52'47.31"N	6°54'24.16"E
P9	36°52'51.66"N	6°54'33.99"E	P24	36°52'50.20" N	6°54'31.30"E
P10	36°52'51.86"N	6°54'33.36"E	P25	36°52'50.52"N	6°54'32.08"E
P11	36°52'52.29"N	6°54'32.45"E	P26	36°52'49.40" N	6°54'27.90"E
P12	36°52'51.20"N	6°54'30.89"E	P27	36°52'50.27"N	6°54'28.51"E
P13	36°52'50.97"N	6°54'30.72"E	P28	36°52'47.32"N	6°54'31.08"E
P14	36°52'50.46"N	6°54'29.33"E	P29	36°52'49.65"N	6°54'31.11"E
P15	36°52'50.23"N	6°54'28.51"E	P30	36°52'52.47"N	6°54'25.18"E

In the following table, we summarize the measurement schedule, points of measurement, and the initial results:

points	leq	Attendance		points	leq	Attendance	
		ISO	WHO			ISO	WHO
P1	74	Noisy	Noisy	P16	91	Noisy	Noisy
P2	78	Noisy	Noisy	P17	81	Noisy	Noisy
P3	73	Noisy	Noisy	P18	87	Noisy	Noisy
P4	91	Noisy	Noisy	P19	73	Noisy	Noisy
P5	77	Noisy	Noisy	P20	70	Moderately noisy	Noisy
P6	90	Noisy	Noisy	P21	70	Moderately noisy	Noisy
P7	90	Noisy	Noisy	P22	68	Moderately noisy	Noisy
P8	79	Noisy	Noisy	P23	67	Moderately noisy	Noisy
P9	81	Noisy	Noisy	P24	91	Hight	Noisy

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P10	60	Comfort	Noisy	P25	67	Moderately noisy	Noisy
P11	68	Moderately noisy	Noisy	P26	59	Comfort	Noisy
P12	91	Noisy	Noisy	P27	70	Hight	Noisy
P13	85	Noisy	Noisy	P28	83	Hight	Noisy
P14	73	Noisy	Noisy	P29	69	Moderately noisy	Noisy
P15	69	Moderately noisy	Noisy	P30	75	Noisy	Noisy

RESULTS

The noise levels recorded at The Liberty Square in Skikda vary between 59 dB at the quietest point (P26) and 91 dB at the most exposed points (P4, P6, P12, P16 and P24), with an overall average of around 78 dB across the entire site, which is nearly 20 dB above the comfort threshold recommended by the World Health Organisation.

This acoustic intensity reveals significant and consistent noise pollution across the entire surface of the square. The highest values (greater than or equal to 85 dB) are mainly found at the edges of the square, near roads and public transport stops, which are directly affected by motor vehicle traffic. Intermediate levels, between 70 and 80 dB, are characteristic of the centre of the square and the semi-open pedestrian areas, slightly attenuated by the presence of surrounding buildings. Lower values (≤ 70 dB) are observed in partially sheltered or vegetated areas, particularly near benches and side corners, although they remain above the acoustic comfort threshold. In terms of time, between 10 a.m. and 11 a.m., variations remain low, with the average noise level remaining consistently high.

This reflects structural noise pollution due to continuous traffic and regular urban activity, rather than occasional noise peaks.

The following map indicates the Noise Distribution:

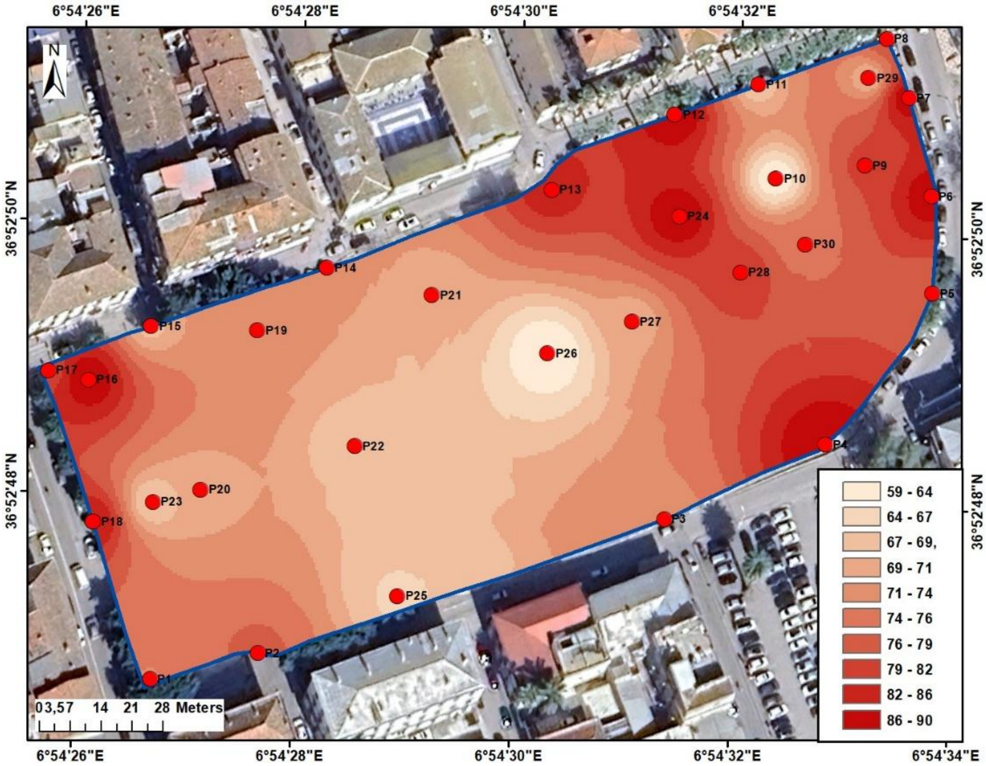

Figure 3: Noise Distribution in The Liberty Square

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DISCUSSION

The results indicate that the Liberty Square is affected by widespread and persistent noise pollution due to several causes, considering;

This place is located in a residential area, next to an administrative district, and also surrounded by roads of very heavy traffic.

The bad habits, in general, of Algerian drivers are using the horn randomly (for any purpose).

The existence of urban transport parking areas inside this place.

Human activities related to gatherings, cafeterias, and shops, especially Algerians' traditional games.

Added to this is sound reverberation, amplified by the square's architectural configuration, which reinforces the propagation of noise throughout the space. The open, mineral morphology of the site accentuates the diffusion of sound waves. The vertical facades and hard surfaces, primarily concrete and stone, create a resonance effect that increases the perceived noise level by several decibels.

The absence of natural barriers, such as vegetation, topography, or absorbent furniture, prevents natural noise attenuation.

With an average level of around 78 dB, the square presents uncomfortable acoustic conditions for prolonged exposure. This constant noise directly affects the perception of the place, leading to auditory saturation and a sense of stress among users. It also affects visitor numbers and the quality of the visitor experience, with visitors tending to shorten their stays.

Finally, this noise pollution alters the square's symbolic and social value, gradually eroding its functions as a place for relaxation and socializing. The Liberty Square, which is supposed to be a space for gathering and well-being, is thus being transformed into a restrictive sound environment. Acoustic and urban redevelopment is necessary to restore its attractiveness and its role within the urban fabric of Skikda.

SIMULATION RESULTS

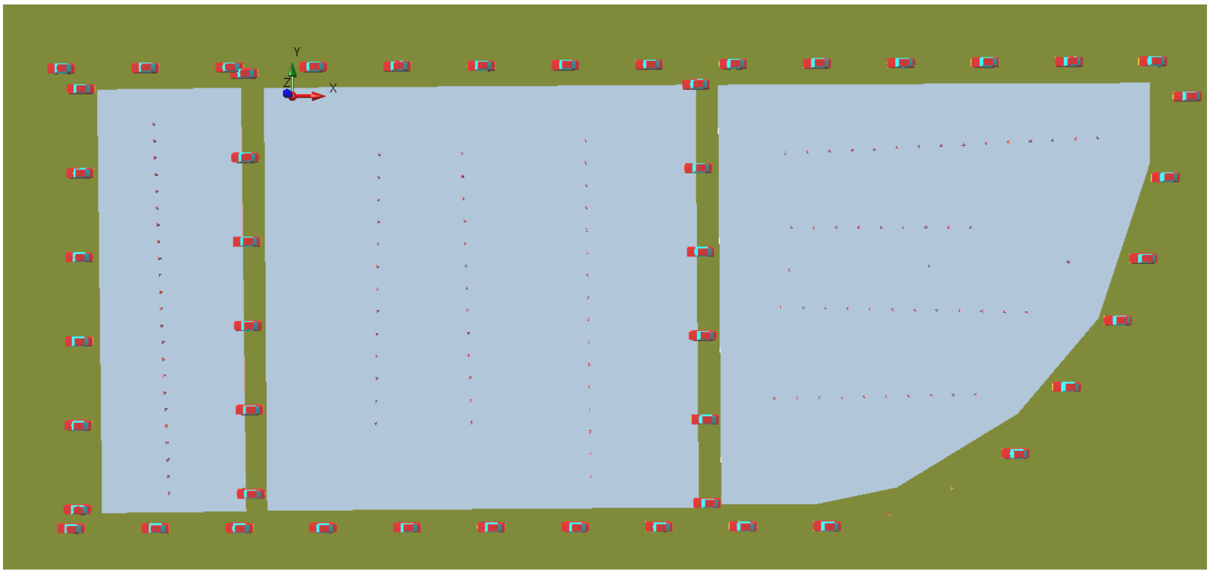

Figure 4: The Liberty Square boundary simulation and car distribution using the Olive Tree Lab software

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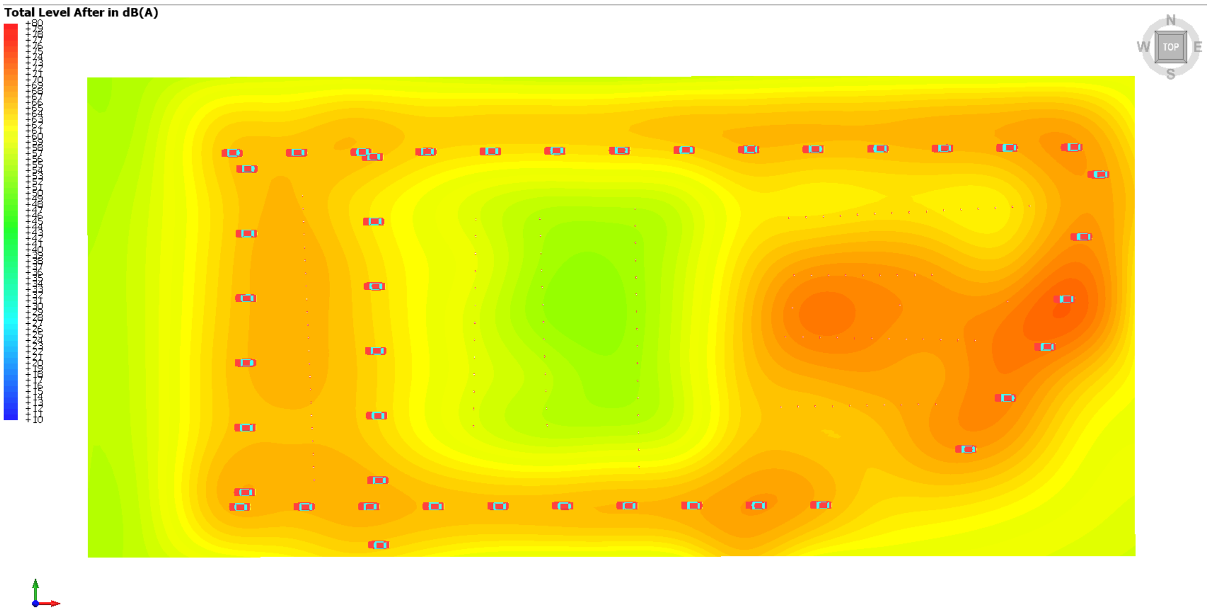

Figure 5: Simulation of Noise Distribution in The Liberty Square using the Olive Tree Lab software

The sound map generated with the Olive Tree Lab suite for "The Liberty Square" in Skikda provides a visual representation of noise levels in the area. Here's a deep interpretation based on the image:

Color Gradients: The color gradients represent different levels of noise intensity. Warmer colors (red) indicate higher noise levels, while cooler colors (green) represent lower noise levels. This allows for a quick visual assessment of the noise distribution in the area.

Sound Sources: The small square icons scattered across the map likely represent specific locations where sound measurements were taken or simulated. These could be the sources of noise you mentioned, such as people and traffic.

Noise Distribution: The right side of the map has a more intense coloration, suggesting higher noise levels possibly due to traffic or other urban activities. This could be a point of focus for noise mitigation strategies.

dB(A) Values: The scale on the left side provides a reference for interpreting the dB(A) values associated with each color on the map. These values can be used to quantify the noise levels at different points in the area.

The sound map you've provided gives a visual representation of the noise power in dB at different locations around the "The Liberty Square" in Skikda. Here's a more detailed interpretation:

Car Noise: The small car icons around the square likely represent the noise generated by traffic. The areas around these icons are colored from yellow to red, indicating moderate to high noise levels.

Color Interpretation: The color gradient on the map represents the noise power in dB. According to the legend on the left:

Blue areas represent the quietest regions, likely farthest from the noise sources.

Green to Yellow areas suggest a moderate noise level, possibly where the noise from people and distant cars blends.

Orange to Red areas indicate high noise levels, likely close to heavy traffic or large crowds.

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Noise Distribution: The noise seems to be most intense (red) near some cars, suggesting that traffic significantly contributes to the noise level. The central square area, despite being surrounded by cars, appears mostly yellow, indicating a moderate noise level. This could be due to the open space, which allows the sound to disperse.

CONCLUSION

This study provides a comprehensive characterization of the soundscape at "The Liberty Square " in Skikda, Algeria, revealing severe and persistent noise pollution. The integration of in-situ measurements and digital modeling using Olive Tree Lab software confirmed that sound pressure levels (average 78 dB(A), reaching 91 dB(A)) consistently exceed both the WHO and ISO 1996 comfort thresholds.

The analysis identifies road traffic as the dominant noise source, exacerbated by local driving habits, the proximity of urban transport hubs, and the square's mineral architectural morphology, which promotes sound resonance and reverberation. The current acoustic environment not only compromises the physical and mental well-being of users but also threatens the symbolic and social value of this historic heritage site.

To restore the square's function as a space for relaxation and social interaction, urgent urban interventions are required. This study recommends a multi-faceted mitigation strategy, including the implementation of dense green barriers (utilizing the site's existing diverse vegetation), the expansion of pedestrian-only zones, and a strategic reorganization of traffic flows. Future research should expand on these findings by incorporating longitudinal temporal data and qualitative user perception surveys to develop more context-sensitive urban acoustic designs.

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