

Article

A Multi-Criteria Soundscape Framework for Neighborhood Noise Planning: A Pilot Study in Tripoli, Lebanon

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Abstract

Urban noise pollution is considered to be a significant challenge to neighborhood livability, particularly in cities with limited noise governance. This has resulted in raising the environmental noise as a critical health and livability concern. Existing approaches rely on decibel thresholds that fail to capture the spatial, social and perceptual complexity of noise conditions at the neighborhood scale. This study offers a multi-criteria soundscape framework integrating acoustic measurements and urban parameters (urban design, landscape, regulations and perception). The aim is to support the optimal location for noise planning. The framework was applied as a pilot study across five residential neighborhoods in Tripoli, Lebanon. The OpeNoise mobile application was used across four temporal sessions. Recordings were combined with qualitative resident interviews. Average Equivalent Continuous Sound level LAeq(t) values ranged from 60.3 to 76.8 dBA. While all neighborhoods exceeded the World Health Organization WHO guidelines, acoustic severity alone did not determine the best case for intervention. The neighborhood with the highest measured noise did not achieve the highest priority score. This demonstrates that decibel planning is insufficient. The alignment of acoustic severity, feasibility, and community demand is more effective for intervention. The framework's criteria are based on observable urban indicators, suggesting applicability to similar urban contexts, further pending validation.

Keywords: urban soundscape; neighborhood; noise planning; multi-criteria framework; urban noise assessment; Tripoli Lebanon; pilot study



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1. Introduction

Rapid urbanization and increasing traffic have significantly increased noise exposure in residential neighborhoods. Exposure to high levels of traffic noise is associated with a range of health problems, including cardiovascular disease, sleep disturbance and annoyance [1,2]. Sustainable Development Goal (SDG) 11 calls for sustainable cities and communities and reducing traffic noise is one of the ways to achieve this goal. In such contexts, noise is no longer an environmental outcome but a critical factor of residential livability.

Common noise mitigation strategies have relied on large-scale infrastructure solutions. However, these methods are often incompatible with the spatial complexity of residential streets. Noise management in many urban contexts remains limited. It often relies on decibel thresholds, lacking the perspective of the residents. Recent research on soundscapes has shifted the focus from only quantitative noise reduction to a better understanding of

acoustic environments. It shows the connection between measured noise levels, urban form, and perception [3]. Tools for noise planning are limited, particularly in Middle Eastern cities. Existing approaches address only part of the neighborhood selection process; noise mapping focuses on decibel levels, soundscape studies emphasize perception, and existing planning frameworks do not support acoustic intervention planning. This study presents the first neighborhood-scale framework to integrate acoustic severity, urban morphology, regulatory capacity, resident perception, and intervention feasibility into a single tool, applied in a Middle Eastern residential context. The proposed framework advances neighborhood noise planning by demonstrating that intervention priorities cannot be identified using decibel-based assessments alone.

Tripoli, Lebanon's second-largest city, reflects this gap. Its dense urban areas, traffic, and limited noise control contribute to high levels of noise exposure. No tool currently exists to guide intervention. This study addresses this gap by developing and testing a multi-criteria soundscape framework. It is designed as a noise planning tool for five residential neighborhoods. It integrates acoustic measurements, assessments of urban design and landscape, and resident perceptions. This study demonstrates that acoustics, intervention, and community converge independently. Prioritizing sites by noise level alone produces different, and less effective, outcomes than a multi-criteria approach.

The framework is a pre-intervention tool, not an intervention design tool. Its purpose is to identify and rank neighborhoods by their readiness for future noise intervention. Potential interventions at priority sites may include green noise barriers or building morphology modifications. Vegetation-based interventions have demonstrated measurable noise attenuation in urban residential contexts [4]. This paper is organized as follows. Section 2 reviews the literature and identifies the research gap. Sections 3 and 4 present the methodology and results. Sections 5 and 6 discuss the findings and conclude the study.

2. Literature Review

2.1. Soundscape Theory and Urban Acoustic Perception

A study conducted by P. Jennings and R. Cain (2013) found that a soundscape cannot be defined by numerical metrics alone [5]. Soundscape theory considers the acoustic environment as perceptual. It is shaped by the interaction between sound sources, spatial context, and human experience. This approach was recognized in [3]. Jennings and Cain (2013) [5] demonstrate that soundscapes' perception depends on the composition, directionality, and temporality of sources. These are criteria that decibel metrics fail to capture. Perception means that effective soundscape assessment must account for several factors. These include activity patterns, demographics, and spatial characteristics [5]. Research confirms that qualitative criteria of the acoustic environment are as important as quantitative thresholds [6]. Noise annoyance has been shown to vary among individuals exposed to identical sound pressure levels [7]. At the neighborhood scale, spatial and environmental characteristics include vegetation, building configuration, street morphology, and land-use patterns [8]. The gap between decibel measurements and residents' experience forms the basis of the multi-criteria soundscape framework proposed in this study.

2.2. Urban Noise Assessment and Emerging Measurement Tools

Urban noise assessment has relied on objective acoustic indicators. These include equivalent continuous sound levels (LAeq) [9]. Noise mapping remains the dominant planning tool for identifying high-exposure areas. However, decibel evaluations provide insufficient information about perceptual impact. These conditions matter most at the neighborhood level, where daily exposure occurs [10]. Smartphones have expanded the geographical and temporal conditions of noise data. They enable neighborhood assess-

ments where governance is limited [11,12]. Citizen-based mobile sensing frameworks have demonstrated the feasibility of participatory sound assessment at city scale, supporting the use of smartphone applications as legitimate acoustic monitoring tools [13]. OpeNoise was developed by ARPA Piemonte, Italy [14]. It represents a validated example of this approach. It shows measurement accuracy of ± 1 dB compared to calibrated sound level meters. This is within environmental noise ranges of 45–80 dB(A) [14]. It also shows confirmed amplitude linearity from 35 to 110 dB on iOS devices. Most urban noise assessments lack guidance [15]. Scholars argue that acoustic measurements must be combined with urban characteristics. These include land use, population, traffic, and green coverage [16]. These criteria are the foundation of the study.

The World Health Organization (WHO) provides guideline values for noise in residential areas. These guidelines aim to minimize health impacts (including sleep disturbance, stress, and reduced quality of life). WHO recommends nighttime noise levels below 45 dB(A) LAeq and daytime levels below 53 dB(A) LAeq, see Table 1 [9].

Table 1. WHO environmental noise guidelines for residential areas and associated health impacts. Source: [9].

Noise Level (dBA)	WHO Classification	Health Impact
Below 53	Acceptable—daytime residential	Minimal annoyance
53–65	Moderate exceedance	Moderate annoyance, sleep disturbance risk
65–75	High exceedance	Significant annoyance, cardiovascular risk
Above 75	Severe exceedance	Serious health risk, cognitive impairment

2.3. Neighborhood Morphology and Noise Planning

The shape and layout of a residential neighborhood show how noise propagates through the built environment [17]. In highly dense neighborhood (narrow streets and a high height-to-width ratio), a distinct “enclosure effect” is created [18]. These dense neighborhoods are better suited for modifications like green building envelopes or sound masking designs [19]. In contrast, more open-block neighborhoods allow noise to spread out differently. It creates spatial opportunities for landscaping and green barriers [20,21]. Therefore, evaluating neighborhood morphology in addition to acoustic data is essential to identify not only where noise is highly problematic, but what specific interventions a local community can consider [17,21].

2.4. Multi-Criteria Approach in Urban Planning

The complexity of residential environments requires urban planning tools capable of evaluating multiple indicators [22]. Traditional urban planning has relied on technical metrics (decibel thresholds) that lack details [22]. To bridge this gap, Multi-Criteria Decision-Making (MCDM) frameworks have been integrated into sustainable urban planning [22,23]. Within noise planning, a multi-criteria approach allows researchers to balance objective thresholds with qualitative conditions and institutional parameters [24]. Therefore, evaluating urban sites, through a multi-criteria matrix, ensures that interventions are not just where noise is highest, but where spatial feasibility and public alignment intersect [23,24]. Multi-criteria approaches to environmental quality have been explored across building typologies, including studies on wellbeing in public spaces [25,26], and the multi-criteria assessment of road traffic noise [27] demonstrated the versatility of weighted scoring frameworks across acoustic planning contexts.

3. Methodology

3.1. Research Design

This research adopts a mixed-method approach. It integrates quantitative noise analysis with qualitative assessment. It aims to develop and implement a multi-criteria soundscape framework for urban noise planning. The methodology combines objective noise measurements with urban indicators, see Figure 1. The framework is designed as a decision support tool using comparisons across neighborhoods. Equal weighting was applied across all criteria to ensure urban and social feasibility consistent with soundscape approaches.

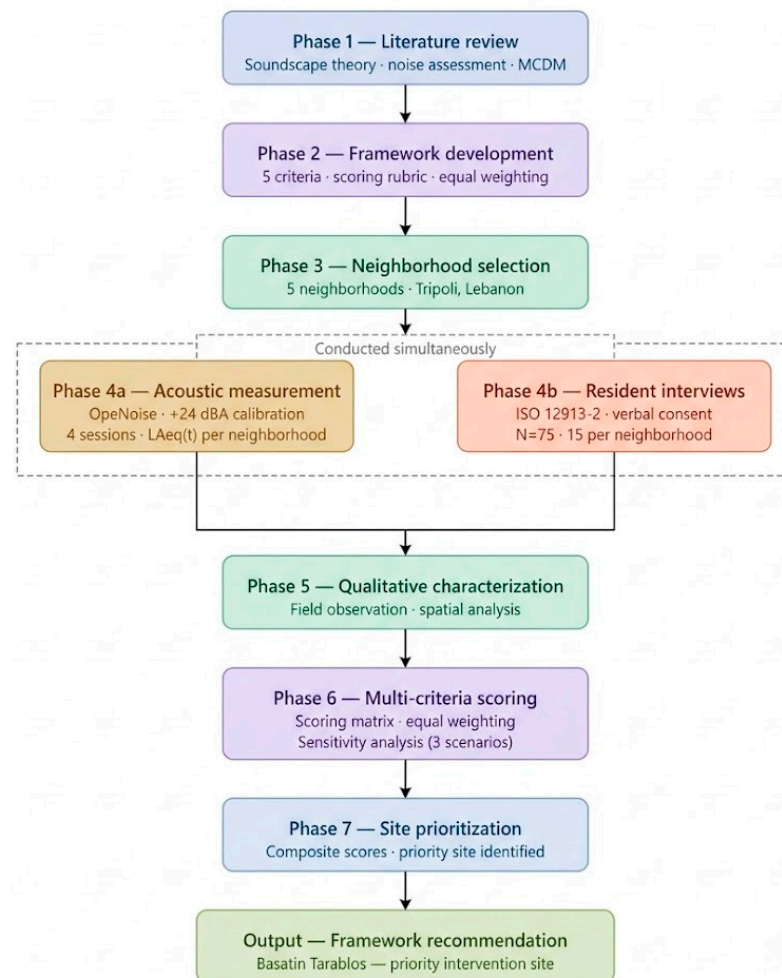


Figure 1. Research methodology flowchart illustrating the sequential and parallel phases of the multi-criteria soundscape framework application. Source: Author's own work.

3.2. Multi-Criteria Framework for Site Selection

The criteria for selecting the soundscape are based on earlier studies that showed that sound pressure levels alone cannot fully convey the effects of urban noise. Recent research has begun classifying soundscape design into typologies to support planning decisions [28]. Soundscape research has shown that acoustic comfort is shaped by contextual and perceptual factors [3]. Evidence shows that land-use patterns affect noise perception [6,16,29]. Moreover, institutional capacity determines whether interventions can be effectively implemented [9]. Perceptual criteria show that demographics, proximity to noise sources and daily activity shape residents' acoustic experience. Annoyance and activity pattern are essential for soundscape assessment [5]. These components represent a

methodology for case study selection that links acoustic severity with urban, environmental, and social contexts, see Table 2. Equal weighting was adopted because no established evidence supports assigning greater importance to any criterion for neighborhood-scale acoustic intervention planning. Expert-based weighting methods such as AHP require expert panels or historical data, which were not available for this pilot study. The sensitivity analysis in Section 3.6 confirmed that the priority ranking remained consistent under alternative weighting scenarios. This indicates that the results are not dependent on the equal weighting assumption.

Table 2. Soundscape-based multi-criteria framework integrating different criteria for neighborhood case study selection. Source: Author’s own work.

Criteria	Sub-Criteria	Scoring Rubric (1–5)
1. Acoustic Conditions	L _{Aeq} (t) dBA, contextual relevance	1 = Low exposure (<55 dBA), 3 = Moderate (55–65 dBA), 5 = High exposure (>65 dBA)
2. Urban Design	Contextual urban design, green infrastructure, public participation	1 = No community organization or civic engagement observed, 3 = Some informal community presence, inconsistent engagement, 5 = Active civic groups, strong community support for intervention
3. Landscape	Outdoor environment design	1 = No usable public space, poor pedestrian infrastructure, 3 = Limited outdoor space, partial green coverage, 5 = Well-maintained public spaces, green elements, space available for intervention
4. Regulatory Context	Regulatory and institutional work	1 = Strong regulatory control, low intervention need, 3 = Partial regulation, moderate need, 5 = Absent or weak regulation, high intervention need
5. Perception	Population density, distance from noise sources, activity intensity	1 = Low annoyance, low community demand, 3 = Moderate annoyance, some community awareness, 5 = High annoyance, strong community support for intervention

3.3. Study Context and Neighborhood Selection

Tripoli is a coastal city rich in history. It is characterized by dense urban fabrics, mixed land uses, traffic, and limited green spaces. Tripoli has a historic urban fabric with a rich architectural heritage and dense urban form. Studies have shown that managing this built environment is a complex task [30]. Homes, businesses, and transportation are in proximity. This produces high noise exposure. The absence of noise management makes Tripoli a relevant case for a multi-criteria approach. It addresses soundscape research in Middle Eastern cities. Previous urban studies have documented the broader institutional challenges facing Tripoli. These studies show that regulatory limitations affect several planning areas, including building codes and noise governance [31,32].

Five residential neighborhoods in Tripoli were selected: Basatin Tarablos, Dam W Farez, El Mina, Abou Samra, and Qobbe. Selection was done by spatial analysis using Google Maps (version 2026) and local field knowledge; see Figure 2. The neighborhoods include diversity across land-use, population density, traffic, and green coverage. The morphological diversity reflected the majority of urban fabrics across Tripoli and comparable Middle Eastern cities (from coastal exposure in El Mina to high traffic in Basatin Tarablos). El-Mina has a unique coastal setting and an active waterfront. Previous studies have explored these features as part of landscape urban revitalization projects [33]. Street geometry and building density vary providing diversity in typology (from narrow dense streets in Dam W Farez to more open blocks in Basatin Tarablos). Environmental quality

ranges from moderate in Elmina and Basatin Tarablos to very limited in Abou Samra and Qobbe. The neighborhoods differ in community engagement and demographics supporting the framework's potential applicability beyond the Tripoli context, see Table 3. Five neighborhoods were considered sufficient for this pilot study. The number aligns with pilot-scale MCDM urban planning studies in the literature.

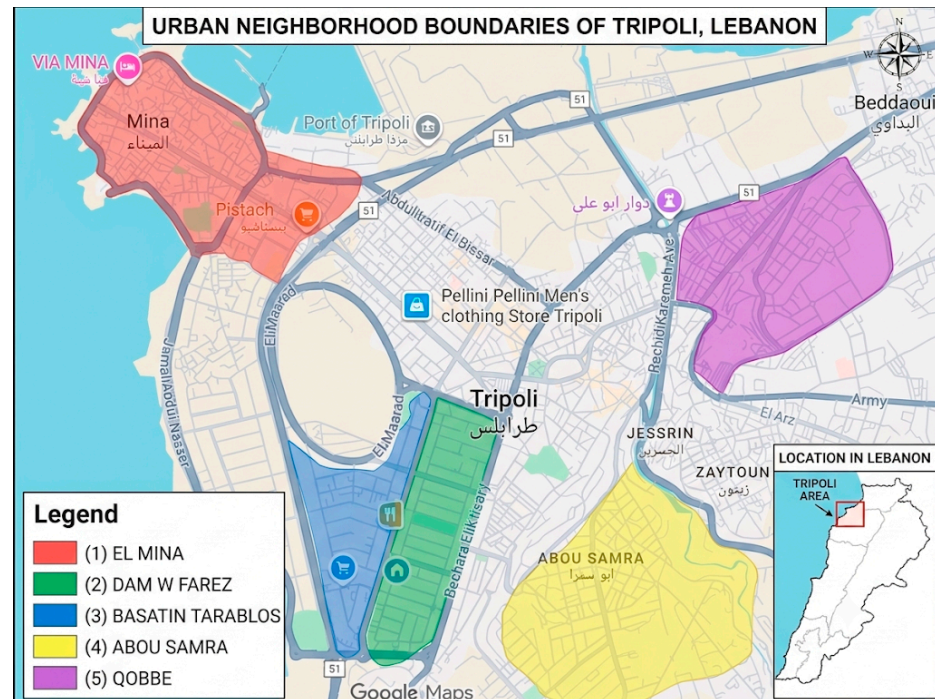


Figure 2. Spatial distribution of the five studied neighborhoods within Tripoli, indicating the locations selected for comparative soundscape assessment. Source: Author's own work.

Table 3. Summary of urban characteristics, land use, traffic conditions, and dominant noise sources across the five studied neighborhoods in Tripoli. Source: Author's own work.

Neighborhood	Approx. Density (People/km ²)	Main Land Use	Traffic Volume	Main Noise Sources	Urban Notes
Basatin Tarablos	~18,000	Residential, Mixed-use, commercial	High	School traffic, construction, social buzz	Well-kept streets, green patches, active community
Dam W Farez	~22,000	Residential, commercial	Moderate	Traffic, workers	Dense streets, limited green areas
El Mina	~19,000	Coastal mixed-use	Moderate	Market and waterfront activity	Walkable, lively social life
Abou Samra	~25,000	Residential-commercial	High	Continuous traffic, pedestrian movement	Compact buildings, poor noise control
Qobbe	~20,000	Institutional-residential	High	Student and vehicle movement	Institutional area, weak regulation

The five neighborhoods represent the main urban forms in Tripoli: coastal mixed-use, dense commercial–residential, institutional–residential, high-density compact urban, and established residential areas with green spaces. This diversity, based on field observations and population density data, was intended to test the framework under different urban conditions rather than in similar neighborhoods. Although a formal cluster analysis was not performed, the selected neighborhoods represent the range of urban forms commonly found in Middle Eastern cities of similar size. This supports the framework’s potential to be applied in similar contexts.

3.4. Noise Measurement Instrument and Calibration Protocol

Noise data were collected using OpeNoise Meter 3.3.0, an open-source application. Measurements included real-time A-weight equivalent continuous sound levels (LAeq1s) and overall LAeqT. Fast Fourier Transform (FFT) spectra and one-third octave band spectra were also recorded. All data was exportable for further analysis. The application’s acoustic validity has been confirmed by Brambilla and Pedrielli [14]. OpeNoise is positioned as a suitable instrument for comparative neighborhood study. All measurements were conducted on a single iOS device. A calibration offset of +24.0 dBA was applied before data collection, see Figure 3. The same iOS device model was used for all measurements across the four sessions and five neighborhoods equally. As a result, any systematic measurement error affected all neighborhoods equally, allowing reliable comparisons. This approach is supported by Kardous & Shaw [34]. They found that smartphones of the same iOS model produce consistent measurements under identical conditions. This preserves the validity of comparative assessments across neighborhoods. Although formal validation against a Class 1 or Class 2 sound level meter was not conducted in this study, future studies should include parallel measurements with professional sound level meters to verify absolute measurement accuracy. Smartphone applications have been evaluated against calibrated sound meters and showed acceptable accuracy [34]. The device was held at 1.5 m above ground level. It was placed at a minimum distance of 3.5 m from surfaces. It was oriented toward the noise source. This ensured the validity of comparative assessments. Acoustic measurements were conducted across four sessions in each neighborhood: Saturday noon, Monday morning, Friday morning, and Wednesday evening. At each measurement point, OpeNoise was operated for a minimum of two minutes.

3.5. Qualitative Resident Interviews

Semi-structured interviews were conducted across neighborhoods to capture residents’ point of view. The interview methodology followed International Organization for Standardization ISO 12913-2 [35] protocols for soundscape data collection. Participants were recruited using street sampling. Participation was entirely voluntary, no compensation was provided, and the academic purpose of the study was verbally explained to obtain consent before interviewing. All interview responses were recorded anonymously, with no personal identifying information collected at any point, ensuring full participant confidentiality throughout the study. A total of 75 participants across five neighborhoods constitutes an appropriate sample for a pilot study. A minimum of 15 participants per site is consistent with qualitative and mixed-methods soundscape research, see Table 4. The sample size of 15 participants per neighborhood is not statistically representative at a city scale. However, it aligns with standard mixed-methods soundscape pilot studies. In data-scarce urban environments, small-scale interviews are highly useful. They successfully capture localized perceptual patterns. For this pilot study, 15 interviews were sufficient to cross-reference objective decibel data with real resident experiences. Fifteen interviews were conducted in each neighborhood. The targeted sample consisted of 52% male and 48% female re-

spondents, primarily aged 26–60, with a diverse mix of educational backgrounds. All participants self-reported normal hearing conditions during the initial screening question. The interview addressed four criteria aligned with soundscape frameworks. A five-point scale rating from very good to very bad was used. The acoustics were assessed by asking participants about dominant sounds. Support for mitigation was examined through open-ended questions, see Table 5. This criterion was important for evaluating intervention within the proposed framework.

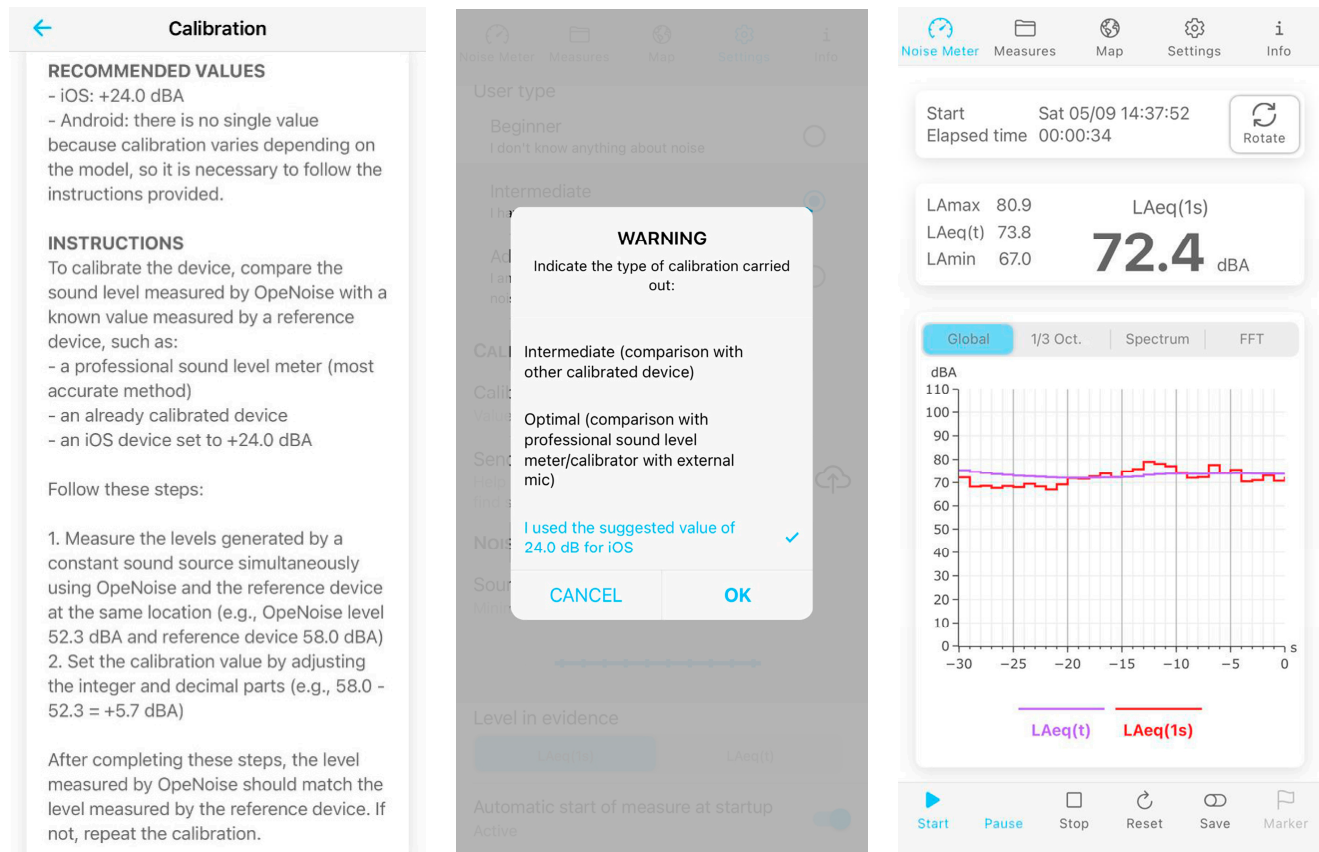


Figure 3. Calibration interface for sound level measurement OpeNoise application.

Table 4. Recommended sample size table based on neighborhood population. Ref. [36] formula.

Neighborhood	Approx. Population	Recommended Sample (95% CI, $\pm 10\%$)	Pilot Study Sample Used
El Mina	~57,000	96	15
Abou Samra	~75,000	96	15
Dam W Farez	~66,000	96	15
Qobbe	~60,000	96	15
Basatin Tarablos	~54,000	96	15
Total	~312,000	480	75 ¹

¹ Population figures are approximate estimates based on density data in Table 3 (people/km²) multiplied by estimated neighborhood area (Lebanon's last official census was conducted in 1932).

Questions were administered during the same time slots as acoustic measurements. This allows direct cross-referencing between measured LAeq(t) conditions and residents' perceived acoustic experience at each location and period.

Table 5. Resident interview questions and corresponding framework criteria, administered verbally during field measurement sessions. Source: Author’s own work.

Interview Question	Framework Criteria
How long have you lived in this neighborhood?	Eligibility screening
How would you rate the overall sound environment here?	Perceptual quality
What sounds do you notice most in this area?	Acoustic characterization
How much do the sounds in this neighborhood bother you in daily life?	Psychological impact
Do you think this neighborhood needs noise reduction measures?	Mitigation support
What would you change about the sound environment here?	Mitigation support

3.6. Sensitivity Analysis Validation

A sensitivity analysis evaluated the framework’s stability against variations in the base-line equal-weighting model. Three planning scenarios were simulated: Scenario 1—acoustic priority: higher weight to acoustic conditions (40%) and distribute remaining 60% equally across the other four criteria. Scenario 2—urban design and landscape priority: higher weight to urban design and landscape combined (40%) and distribute the remaining 60% equally. Scenario 3—perception priority: higher weight to perception dimension (40%) and remaining 60% equally. Results are presented in Section 4.3.

4. Results

4.1. Acoustic Profiles by Neighborhood

Average LAeq(t) values from all four sessions were used as the primary acoustic indicator. Table 6 presents the mean LAeq(t) and descriptive statistics across the four measurement sessions. El Mina and Basatin Tarablos show low standard deviations (SD = 1.00 and SD = 1.15 respectively), indicating consistent and persistent noise exposure regardless of day or time. Dam W Farez similarly shows low variability (SD = 1.19), confirming persistent exposure driven by dense street geometry. In contrast, Abou Samra and Qobbe show higher variability (SD = 3.87 and SD = 3.56), with ranges of 8.1 and 8.3 dB, respectively, reflecting sensitivity to weekend versus weekday activity patterns. Individual sessions were taken to illustrate temporal variation. All five neighborhoods exceeded the WHO daytime residential guideline of 53 dBA. Moreover, Basatin Tarablos recorded the highest average at 76.8 dBA, exceeding this by nearly 24 dB; see Figures 4 and 5. The acoustic profiles constitute the first part of the multi-criteria assessment converting field-measured LAeq(t) values into comparable scores.

Table 6. Acoustic measurement summary across four sessions per neighborhood (LAeq(t) in dBA). Source: Author’s own work.

Neighborhood	Sat Noon	Mon AM	Fri AM	Wed Eve	Mean LAeq(t)	SD	Min	Max	Range	WHO Exceedance
El Mina	59.4	60.2	61.7	59.8	60.3	1.00	59.4	61.7	2.3	+7.3 dB
Abou Samra	72.7	64.6	65.5	70.3	68.3	3.87	64.6	72.7	8.1	+15.3 dB
Dam W Farez	74.8	72.0	73.1	73.9	73.5	1.19	72.0	74.8	2.8	+20.5 dB
Qobbe	73.8	65.5	68.2	70.9	69.6	3.56	65.5	73.8	8.3	+16.6 dB
Basatin Tarablos	77.3	78.1	75.4	76.5	76.8	1.15	75.4	78.1	2.7	+23.8 dB

4.2. Residents’ Perception Findings

The following perception findings complement the acoustic profiles by capturing the experience of neighborhoods. The findings are not statistical results but perception patterns that help us to interpret LAeq(t) values through residents’ experience. Each

neighborhood's perception profile is used to score the matching dimension of the multi-criteria framework. It converts interview insights into scores for acoustic disturbance, community needs, and support for interventions, see Table 7. In El Mina, most residents reported a good soundscape, low disturbance, and little support for noise reduction. In Abou Samra, most residents reported a moderate to poor soundscape, high disturbance, and strong support for intervention. In Dam W Farez, many residents considered the soundscape acceptable despite high measured noise, and most showed limited support for intervention. In Qobbe, most residents reported a poor soundscape and supported noise reduction. Basatin Tarablos showed the highest levels of disturbance, with most residents rating the soundscape as poor and strongly supporting noise reduction measures. Perception scores were based on the interview results and the perception criteria in the scoring rubric. Neighborhoods where most residents reported high noise disturbance identified traffic as the main source of noise and supported noise-reduction measures received higher scores. This indicates a higher priority for intervention.

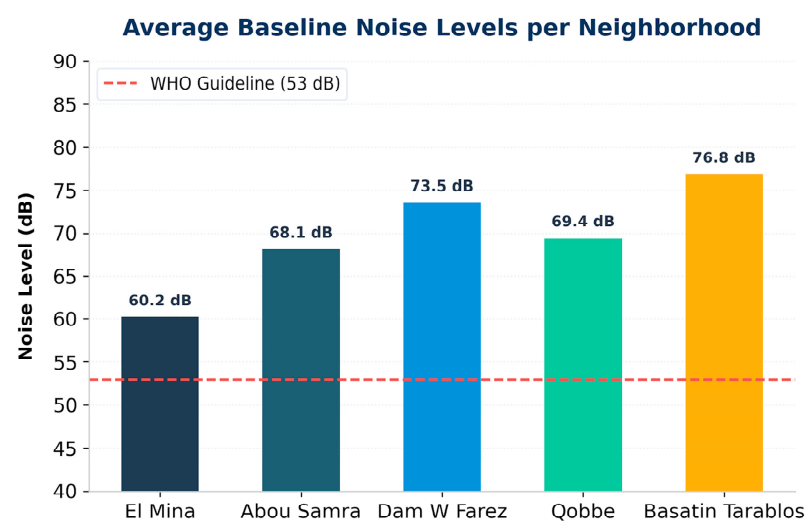


Figure 4. Mean L_{Aeq}(t) by neighborhood with WHO 53 dBA guidelines. Source: Author's own work.

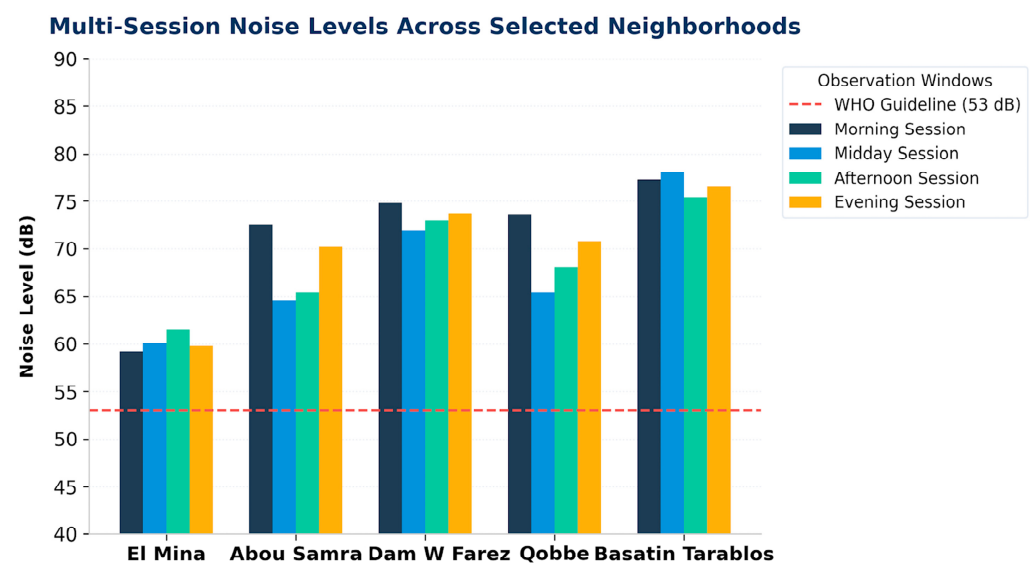


Figure 5. Sessions of L_{Aeq}(t) comparison showing temporal variation across four measurement periods. Source: Author's own work.

Table 7. Resident perception interview summary across five neighborhoods. Source: Author’s own work.

Neighborhood	Dominant Age	Overall Rating	Dominant Sources	Disturbance Level	Support for Intervention
El Mina	41–60	Good	Traffic, voices, commercial	Low	Low
Abou Samra	26–50	Moderate–Bad	Traffic, voices	High	High
Dam W Farez	36–60	Good	Traffic	Low–Moderate	Low
Qobbe	40–60	Bad	Traffic, voices, commercial	High	High
Basatin Tarablos	26–41	Bad	Traffic, construction, commercial	Very high	Very high

4.3. Multi-Criteria Assessment

A morphological assessment was conducted across the five locations to bridge the gap between objective metrics and spatial parameters. Neighborhood acoustics are influenced by the geometric configurations of the residential fabric. Table 8 synthesizes the physical layout (including fabric typology, street geometry, and building density) in addition to LAeq(t) values. This justifies the qualitative criteria scoring within the multi-criteria framework.

Table 8. Morphological configuration and acoustic profile of the studied neighborhoods. Source: Author’s own work.

Neighborhood	Fabric Typology	Street Geometry (Height/Width Aspect)	Building Layout and Density	Average Noise Level (LAeq(t))
El Mina	Coastal Mixed-Use	Moderate to wide corridors (Low-to-Medium aspect ratio)	Discontinuous blocks with active interfaces	60.3 dBA (WHO Exceedance: +7.3 dB)
Dam W Farez	Modern Dense Residential/Commercial	Deep street canyons (High aspect ratio)	Compact, continuous mid-rise blocks with minimal structural gaps	73.5 dBA (WHO Exceedance: +20.5 dB)
Basatin Tarablos	Low-Density Mixed Residential	Open, wide street profiles (Low aspect ratio)	Decentralized, detached open-block configurations	76.8 dBA (WHO Exceedance: +23.8 dB)
Abou Samra	High-Density Compact Residential	Narrow, enclosed street corridors (High aspect ratio)	Highly dense, continuous building envelopes with severe proximity to roads	68.3 dBA (WHO Exceedance: +15.3 dB)
Qobbe	Institutional– Residential Grid	Variable to narrow corridors (Medium-to-High aspect ratio)	Large institutional blocks mixed with compact residential pockets	69.6 dBA (WHO Exceedance: +16.6 dB)

The multi-criteria assessment combines qualitative field observations with acoustic measurements. Each criterion was scored on a scale from 1 to 5. It results in a maximum score of 25. Table 9 presents the qualitative characterization of each neighborhood. It provides the evidence base used to derive numerical scores. Basatin Tarablos achieved the highest composite score (20). This indicates the optimal combination of high noise exposure and suitable urban conditions for intervention. This is in addition to available space and strong community support.

Scores were derived by mapping the qualitative characterizations in Table 9 against the scoring rubric defined in Table 2. Table 10 explains how the scores were assigned for each criterion in the five neighborhoods. Acoustic scores were based on measured LAeq(t) values, while urban design, landscape, and regulatory scores were based on field observations. Perception scores were based on residents’ interview responses about noise disturbance and support for noise reduction measures. This allows each score to be linked to observed evidence, making the framework transparent and reproducible. Table 11 presents the final multi-criteria scoring matrix.

Table 9. Qualitative multi-criteria characterization of five Tripoli neighborhoods. Source: Author’s own work.

Criteria	Sub-Criteria	Basatin Tarablos	Dam W Farez	El Mina	Abou Samra	Qobbe
Acoustic	Noise level	Existing problem during peak hours	Noise issues mainly during peak hours	Noise issues mainly during peak hours	Persistently problematic noise conditions	Persistently problematic noise conditions
	Contextual relevance	High	Moderate	Moderate	High	High
Urban Design	Contextual urban design	Very good	Very good	Good	Weak/inconsistent	Very weak/inconsistent
	Public participation potential	Very good community support	Very good community support	Good community engagement	Random/limited	Very limited/random
	Green infrastructure potential	Moderate	Limited	Moderate	Very limited	Very limited
Landscape	Outdoor environment design	Good	Good	Moderate	Poor	Very poor
Regulatory	Regulatory and institutional framework	Moderate	Moderate	Limited	Weak	Very weak
Perception	Population density pressure	Moderate	High	High	High	Very high
	Distance from noise sources	Moderate proximity	Moderate proximity	Variable proximity	Very close proximity	Very close proximity
	Activity intensity	Moderate–high	Moderate	Moderate	Very high	High
Feasibility	Space availability for intervention	Available	Available	Limited	Very limited	Not available

Table 10. Score justification matrix per neighborhood and criterion. Source: Author’s own work.

Neighborhood	Acoustic	Urban Design	Landscape	Regulatory	Perception
El Mina	2—Avg 60.3 dBA, moderate WHO exceedance	3—Walkable fabric, moderate civic engagement	3—Coastal vegetation, partial spatial availability	2—Partial coastal governance	1—Good rating, low disturbance, low intervention demand
Abou Samra	3—Avg 68.3 dBA, high variable exceedance	2—Compact blocks, weak civic structures	2—Minimal vegetation, limited intervention space	3—Absent noise controls, some commercial licensing	4—High disturbance, strong intervention support
Dam W Farez	4—Avg 73.5 dBA, persistent across all sessions	2—Dense geometry, absent green infrastructure	1—No vegetation, narrow canyons, no feasible space	3—Partial enforcement, some institutional capacity	2—Good rating despite high LAeq, acoustic habituation
Qobbe	4—Avg 69.6 dBA, activity-driven peaks	1—Fragmented spaces, minimal community organization	1—No green infrastructure, spatially constrained	4—Very weak enforcement, high intervention need	4—Bad rating, high disturbance, strong support
Basatin Tarablos	5—Avg 76.8 dBA, highest and most consistent	4—Well-maintained streets, active community, intervention-ready	3—Moderate vegetation, open blocks, space for green barriers	3—Moderate context, limited noise governance	5—Very high disturbance, near-unanimous intervention support

On the other hand, a sensitivity analysis was conducted across the three simulated scenarios. Table 12 presents the calculated weighted average scores. The consistency of results across weighting scenarios supports the robustness of the framework’s outcome. This confirms that the multi-criteria diagnostic tool remains valid. Basatin Tarablos remains

the highest-scoring neighborhood across all four weighting scenarios. A secondary finding: Dam W Farez rises significantly under acoustic priority weighting but remains constrained (acoustically severe but neither spatially ready nor community-driven for change).

Table 11. Scored multi-criteria assessment matrix (1–5 per dimension, maximum 25). Source: Author’s own work.

Neighborhood	Acoustic	Urban Design	Landscape	Regulatory	Perception	Total/25
El Mina	2	3	3	2	1	11
Abou Samra	3	2	2	3	4	14
Dam W Farez	4	2	1	3	2	12
Qobbe	4	1	1	4	4	14
Basatin Tarablos	5	4	3	3	5	20

Table 12. Completed sensitivity analysis table. Source: Author’s own work.

Neighborhood	Equal Weight (/25)	Acoustic Priority (40%)	Urban Design and Landscape Priority (40%)	Perception Priority (40%)
El Mina	11.0	10.8	11.8	9.5
Abou Samra	14.0	14.2	13.2	15.5
Dam W Farez	12.0	14.0	11.2	11.5
Qobbe	14.0	15.5	12.5	15.5
Basatin Tarablos	20.0	21.2	19.2	21.2

5. Discussion

The findings demonstrate that all five neighborhoods exceeded WHO guidelines, yet acoustic severity alone did not determine suitable intervention. This confirms that decibel-based planning produces different and less actionable outcomes than a multi-criteria approach. This finding aligns with [37], who argues that built environment professionals must move beyond the noise differentiation toward integrated approaches: how residents experience their acoustic environment in context. The framework is based on the convergence of acoustic conditions, urban feasibility, regulations and community demand. Table 13 summarizes the relationship between measured noise levels and resident perception findings across all five neighborhoods, highlighting where acoustic severity and perceived disturbance align and where they diverge. Alignment classification indicates the degree of correspondence between objective acoustic exposure and subjective disturbance experience.

Table 13. Comparison of measured LAeq(t) values and residents’ perception findings across the five study neighborhoods. Source: Author’s own work.

Neighborhood	Avg LAeq(t) (dBA)	WHO Exceedance	Overall Perception	Disturbance Level	Intervention Support	Acoustic Score	Perception Score	Alignment
El Mina	60.3	+7.3 dB	Good	Low	Low	2/5	1/5	✓ Aligned
Abou Samra	68.3	+15.3 dB	Moderate–Bad	High	High	3/5	4/5	✓ Aligned
Dam W Farez	73.5	+20.5 dB	Good	Low–Moderate	Low	4/5	2/5	✗ Divergent
Qobbe	69.7	+16.6 dB	Bad	High	High	4/5	4/5	~ Partial
Basatin Tarablos	76.8	+23.8 dB	Bad	Very high	Very high	5/5	5/5	✓ Aligned

Dam W Farez averaged 73.5 dBA. However, residents reported low disturbance and limited demand for intervention. This divergence is explained by acoustic habituation of

long-term residents. This extends [5,15] into a Middle Eastern residential context. Basatin Tarablos proves the complementary point: the highest noise, the strongest community demand, the most available space and the most favorable urban design conditions. This matches [29], who argue that morphology and green infrastructure must be evaluated in addition to acoustics. Furthermore, it aligns with [16], who argue that intervention depends on feasibility and community engagement. The qualitative characterization table translates these theories into a practical tool. Basatin Tarablos (with its wider streets, open-block layout, and low height-to-width ratio) offers capacity for effective interventions, whereas Dam W Farez (characterized by compact mid-rise blocks and deep street canyons) traps noise while limiting available space for interventions. These contrasting morphological profiles show that urban form shapes both noise exposure and intervention feasibility. This confirms the need to integrate morphology as a core dimension in acoustic planning.

This neighborhood scale framework provides a useful tool for applying the findings to other Middle Eastern and Mediterranean cities. The proposed multi-criteria approach can be used as two-stage tool. First, neighborhoods are ranked according to noise, community and need. Second, the urban morphology of the selected neighborhood is analyzed to see its relationship with noise impact. This optimizes data collection and provides a scalable approach. It links community needs and acoustic conditions with the physical characteristics of the urban environment.

This study has several limitations. The interview component with 15 participants per neighborhood provides perceptions rather than statistics. Future “Phase 2” research should include larger sample sizes. Frameworks should incorporate focus groups and narrative analysis. Focus groups will help researchers observe community and noise perceptions in real time. Narrative analysis will help work on the psychological impacts of noise exposure on residents. These qualitative insights will provide a more robust foundation for the framework’s scoring logic. Although a basic sensitivity analysis was conducted, future research should apply more advanced weighting techniques such as AHP and TOPSIS. Future research should also expand temporal measurement coverage. The sensitivity analysis in Section 3.6 tested three different weighting scenarios and confirmed Basatin Tarablos as the priority site. However, it did not examine all possible weight combinations. Future studies could use a Monte Carlo simulation to test a wider range and generate better intervals for the priority rankings. It should also involve local planning authorities to evaluate the framework. Despite these limitations, the findings demonstrate that soundscape planning is achievable in data-scarce urban contexts.

6. Conclusions

This study developed and tested a five-dimension multi-criteria soundscape framework that any researcher or planner can apply. The aim is to identify priority sites in neighborhoods that lack formal noise management.

The soundscape multi-criteria framework presents a planning tool based on literature review across five distinct domains. It is the first soundscape neighborhood study in Lebanon. It demonstrated that acoustic assessment is feasible in Middle Eastern cities despite the absence of monitoring tools. The findings align with theories from European soundscape research, suggesting cross-regional applicability of core soundscape principles. Acoustics and intervention suitability were found to diverge, with the second highest levels (the case of Dam W Farez) showing the lowest community demand for change. Field-based evidence challenges the assumption underlying conventional decibel planning.

Future research should integrate [35] structured surveys with larger samples, apply weighted MCDM methods, and validate the framework across additional Middle Eastern urban contexts. It should also move from site prioritization toward intervention design,

exploring how green noise barriers can be implemented at the identified priority site. Finally, this study contributes a framework that redefines neighborhood noise planning. It shifts from a question of where sound is loudest to a question of where conditions for change most fully converge.

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Abbreviations

The following abbreviations are used in this manuscript:

LAeq	Equivalent Continuous Sound Level
LAeq(t)	Time-averaged Equivalent Continuous Sound Level
dBA	A-weighted Decibels
WHO	World Health Organization
ISO	International Organization for Standardization
MCDM	Multi-Criteria Decision Making
AHP	Analytic Hierarchy Process
OpeNoise	Open Noise—Mobile Acoustic Measurement Application
FFT	Fast Fourier Transform
SDG	Sustainable Development Goals

References

1. Münzel, T.; Gori, T.; Babisch, W.; Basner, M. Cardiovascular effects of environmental noise exposure. *Eur. Heart J.* **2014**, *35*, 829–836. [[CrossRef](#)] [[PubMed](#)]
2. Münzel, T.; Sørensen, M.; Daiber, A. Transportation noise pollution and cardiovascular disease. *Nat. Rev. Cardiol.* **2021**, *18*, 619–636. [[CrossRef](#)] [[PubMed](#)]
3. *ISO 12913-1:2014; Acoustics—Soundscape—Part 1: Definition and Conceptual Framework*. ISO: Geneva, Switzerland, 2014.
4. Kumar, M.; Gautam, C.; Garg, N.; Snehlata; Rajlaxmi, A. Effect of Vegetation in Abatement of Noise Pollution: A Soundscape Approach. In *Handbook of Vibroacoustics, Noise and Harshness*; Garg, N., Ed.; Springer: Singapore, 2024; pp. 1–20. [[CrossRef](#)]
5. Jennings, P.; Cain, R. A framework for improving urban soundscapes. *Appl. Acoust.* **2013**, *74*, 293–299. [[CrossRef](#)]
6. Van Renterghem, T. Towards explaining the positive effect of vegetation on the perception of environmental noise. *Urban For. Urban Green.* **2019**, *40*, 133–144. [[CrossRef](#)]
7. Mitchell, A.; Erfanian, M.; Soelistyo, C.; Oberman, T.; Kang, J.; Aldridge, R.; Xue, J.; Aletta, F. Effects of Soundscape Complexity on Urban Noise Annoyance Ratings: A Large-Scale Online Listening Experiment. *Int. J. Environ. Res. Public Health* **2022**, *19*, 14872. [[CrossRef](#)] [[PubMed](#)]

8. Aletta, F.; Kang, J.; Axelsson, Ö. Soundscape descriptors and a conceptual framework for developing predictive soundscape models. *Landsc. Urban Plan.* **2016**, *149*, 65–74. [\[CrossRef\]](#)
9. World Health Organization. *Environmental Noise Guidelines for the European Region*; WHO Regional Office for Europe: Copenhagen, Denmark, 2018.
10. Murphy, E.; King, E.A. *Environmental Noise Pollution: Noise Mapping, Public Health, and Policy*; Elsevier: Amsterdam, The Netherlands, 2014.
11. Maisonneuve, N.; Stevens, M.; Niessen, M.E.; Steels, L. NoiseTube: Measuring and mapping noise pollution with mobile phones. In *Information Technologies in Environmental Engineering*; IE&EM 2010; Springer: Berlin/Heidelberg, Germany, 2010; pp. 15–28.
12. Torija, A.J.; Ruiz, D.P. A general procedure to generate models for urban environmental-noise pollution using feature selection and machine learning methods. *Sci. Total Environ.* **2015**, *505*, 680–693. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Can, A.; Audubert, P.; Aumond, P.; Geisler, E.; Guiu, C.; Lorino, T.; Rossa, E. Framework for urban sound assessment at the city scale based on citizen action, with the smartphone application NoiseCapture as a lever for participation. *Noise Mapp.* **2023**, *10*, 20220166. [\[CrossRef\]](#)
14. Brambilla, G.; Pedrielli, F. Smartphone-Based Participatory Soundscape Mapping for a More Sustainable Acoustic Environment. *Sustainability* **2020**, *12*, 7899. [\[CrossRef\]](#)
15. Ouis, D. Annoyance from road traffic noise: A review. *J. Environ. Psychol.* **2001**, *21*, 101–120. [\[CrossRef\]](#)
16. Kang, J.; Schulte-Fortkamp, B. (Eds.) *Soundscape and the Built Environment*; CRC Press: Boca Raton, FL, USA, 2016.
17. Estévez-Mauriz, L.; Forssén, J.; Kropp, W.; Zachos, G. Urban space and the sound environment: Transport system, urban morphology, quiet side and space users in the SONORUS project. In Proceedings of the 45th International Congress and Exposition on Noise Control Engineering: Towards a Quieter Future (INTER-NOISE 2016), Hamburg, Germany, 21–24 August 2016; pp. 2900–2911.
18. Yilmaz, N.G.; Lee, P.-J.; Imran, M.; Jeong, J.-H. Role of sounds in perception of enclosure in urban street canyons. *Sustain. Cities Soc.* **2023**, *90*, 104394. [\[CrossRef\]](#)
19. Yilmaz, N.G.; Lee, P.-J.; Heimes, A.; Galbrun, L. The influence of natural features and height-to-width ratios on psycho-physiological responses to urban street canyons. *Build. Environ.* **2025**, *276*, 112851. [\[CrossRef\]](#)
20. Meng, Q.; Evgrafova, O.; Li, M. A Predictive Model for Traffic Noise Reduction Effects of Street Green Spaces with Variable Widths of Coniferous Vegetation. *Forests* **2025**, *16*, 238. [\[CrossRef\]](#)
21. Wickramathilaka, N.; Ujang, U.; Azri, S.; Choon, T.L. Influence of Urban Green Spaces on Road Traffic Noise Levels: A Review. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2022**, *XLVIII-4/W3-2022*, 195–201. [\[CrossRef\]](#)
22. Massarelli, C.; Binetti, M.S. Improving Urban Resilience Through a Scalable Multi-Criteria Planning Approach. *Urban Sci.* **2025**, *9*, 309. [\[CrossRef\]](#)
23. Hashemi Sigari, R.; Panagopoulos, T. A Multicriteria Decision-Making Approach for Urban Water Features: Ecological Landscape Architecture Evaluation. *Land* **2024**, *13*, 1799. [\[CrossRef\]](#)
24. Iturbe-Martin, Z.; Martín-Garín, A.; Casado-Rezola, A. Soundscape-Informed Urban Planning and Architecture in Historic Centers: A Multi-Layer Method for Soundscape Characterization Applied to Bilbao Old Town. *Appl. Sci.* **2026**, *16*, 3630. [\[CrossRef\]](#)
25. El-Daghar, K. Applying learning methods with architecture students to improve indoor quality for health and wellbeing in buildings: Case study enhancing lighting efficiency of public spaces. *BAU J. Health Wellbeing* **2018**, *1*, 62. [\[CrossRef\]](#)
26. Leccese, F.; Rocca, M.; Salvadori, G.; Belloni, E.; Buratti, C. A multicriteria method to identify and rank IEQ criticalities: Measurements and applications for existing school buildings. *Energy Built Environ.* **2025**, *6*, 387–401. [\[CrossRef\]](#)
27. Yang, D.; Mak, C.M. An assessment model of classroom acoustical environment based on fuzzy comprehensive evaluation method. *Appl. Acoust.* **2017**, *127*, 292–296. [\[CrossRef\]](#)
28. Chen, X.; Aletta, F.; Moshona, C.C.; Fiebig, A.; Henze, H.; Kang, J.; Mitchell, A.; Oberman, T.; Schulte-Fortkamp, B.; Tong, H. Developing a taxonomy of soundscape interventions from a catalogue of real-world examples. *Acta Acust.* **2024**, *8*, 29. [\[CrossRef\]](#)
29. Margaritis, E.; Kang, J. Relationship between green space-related morphology and noise pollution. *Ecol. Indic.* **2017**, *72*, 921–933. [\[CrossRef\]](#)
30. El-Daghar, K. Self-financing for conservation based on global experiences: Case study preserving the architectural heritage of historical Tripoli, Lebanon. *Resourceedings* **2019**, *2*, 224–236. [\[CrossRef\]](#)
31. Al-Sukkari, T.A.S.; El-Daghar, K.; Galal, K.S.; Afify, A. A roadmap for the implementation of building energy efficiency codes compliance in Tripoli, Lebanon. *Rev. Gestão Soc. Ambient.* **2024**, *18*, e6518. [\[CrossRef\]](#)
32. Al-Sukkari, T.A.S.; El-Daghar, K.; Galal, K.S.; Afifi, A. Towards effective implementation of building energy efficiency codes in Tripoli, Lebanon: Key actions for enforcement. *Herit. Sustain. Dev.* **2024**, *6*, 771–790. [\[CrossRef\]](#)
33. Traboulsi, C.; Khalifa, M.; El Samahy, E.; El-Daghar, K.; Felix, M. Urban waterfront revitalization through landscape design enhancing social-cultural conditions of El-Mina, Tripoli. *Archit. Plan. J.* **2023**, *29*, 5. [\[CrossRef\]](#)
34. Kardous, C.A.; Shaw, P.B. Evaluation of smartphone sound measurement applications. *J. Acoust. Soc. Am.* **2014**, *135*, EL186–EL192. [\[CrossRef\]](#) [\[PubMed\]](#)

35. ISO 12913-2:2018; Acoustics—Soundscape—Part 2: Data Collection and Reporting Requirements. ISO: Geneva, Switzerland, 2018.
36. Cochran, W.G. *Sampling Techniques*, 3rd ed.; John Wiley & Sons: New York, NY, USA, 1977.
37. Steele, D.; Bild, E.; Guastavino, C. Moving past the sound-noise dichotomy: A soundscape approach to urban planning. *Cities* **2023**, *132*, 103974. [[CrossRef](#)]

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