JOURNAL OF APPLIED ENGINEERING SCIENCES
ISSN: 2247-3769 / e-ISSN: 2284-7197

sciendo

VOL. 15(28), ISSUE 2/2025
ART.NO. 467 pp. 311-316

BEYOND DECIBELS: COMPARING CONVENTIONAL AND FULL-SPECTRUM, FREQUENCY-BASED NOISE ASSESSMENT FOR HEALTHIER URBAN ENVIRONMENTS

V. Marusceac [a], Mădălina A. Ciotlăuș [a], Alexandra D. Danciu [a, *], M.L. Dragomir [a]

[a] Technical University of Cluj-Napoca, Faculty of Civil Engineering, Department of Railways, Roads and Bridges, Observatorului 72-74, 400363, Cluj-Napoca, Romania, E-mails: Vladimir.Marusceac@cfdp.utcluj.ro, Madalina.Ciotlaus@cfdp.utcluj.ro, *Alexandra.Danciu@cfdp.utcluj.ro, Mihai.Dragomir@cfdp.utcluj.ro

Received: 02.09.2025 / Accepted: 13.10.2025 / Revised: 25.11.2025 / Available online: 15.12.2025

DOI: 10.2478/jaes-2025-0037

KEY WORDS: noise pollution, mitigation measures, full-spectrum noise, noise levels in intersections, speed barrier noise levels.

ABSTRACT:

Urban noise pollution is a growing concern in contemporary cities, with conventional sound level measurements often failing to accurately capture its spectral complexity. This paper emphasizes the necessity of full-spectrum acoustic measurements, as opposed to traditional dB(A) maximum or average values, which overlook the frequency-specific characteristics of noise sources. Through several case studies conducted in Cluj-Napoca, Romania, involving intersections, speed breakers, and varying urban morphologies, we demonstrate that noise pollution manifests with identifiable spectral patterns. Understanding these patterns is critical for implementing effective and frequency-specific noise mitigation solutions. By comparing standard methodologies with full-spectrum analyses, this study advocates for a paradigm shift in environmental acoustic monitoring practices and urban noise management strategies.

1. INTRODUCTION

1.1 General Instructions

Noise pollution has become a major environmental stressor in modern urban areas, with long-term impacts on public health, quality of life, and economic development. Among all sources, road traffic remains the dominant contributor, accounting for nearly two-thirds of urban noise (EEA, 2019). Urban expansion, increased vehicle ownership, and insufficient integration of acoustical parameters in planning have led to chronic exposure to excessive sound levels, particularly in densely populated residential areas.

Conventional environmental noise assessment typically relies on simplified scalar indicators such as LAeq (equivalent continuous sound level) and Lmax (maximum sound level), measured in dB(A). While these parameters are useful for regulatory purposes, such as those defined in the European Directive 2002/49/EC and ISO 1996 standards, they offer limited insight into the frequency content of noise and its specific spectral impact on human perception (Passchier-Vermeer & Passchier, 2000). As a result, mitigation strategies derived from such aggregate measurements often lack specificity and efficiency.

Full-spectrum acoustic analysis, measuring in 1/3 octave bands from 20 Hz to 20 kHz, provides a more detailed characterization of the sound environment. This methodology allows differentiation between low-frequency rolling noise (typically 50–100 Hz), mid-frequency engine noise (around 500–2000 Hz), and high-frequency transient components such as horns and sirens (above 2 kHz) (Janusevicius & Akelaityte, 2015). These distinctions are critical in identifying dominant sources and in correlating them with urban geometry and material properties.

Case studies in European cities have shown that intersections with frequent acceleration and braking cycles generate high-amplitude noise peaks in the 50–200 Hz range, while traffic-calming devices such as speed breakers can significantly amplify low-frequency components due to suspension and impact effects (Haroon et al., 2022). Moreover, urban morphology—building height, street canyon effects, façade materials, and orientation—has a measurable influence on noise propagation and reflection (Picaut & Simon, 2001; Kang, 2002).

This paper builds upon such findings to compare conventional dB-based noise assessment with full-spectrum measurements in various urban contexts. The goal is to advocate for a shift toward frequency-aware monitoring to enable precise, source-specific noise mitigation strategies.

2. STANDARD MEASUREMENT METHODOLOGIES

In Europe, environmental noise regulation is governed by the Environmental Noise Directive (END) 2002/49/EC, which mandates the preparation of noise maps and action plans for

* Corresponding author: Alexandra Denisa Danciu, Associated Professor PhD Eng, Railways, Roads and Bridges Department, Faculty of Civil Engineering, Technical University of Cluj-Napoca, Romania, e-mail: Alexandra.Danciu@cfdp.utcluj.ro

major sources such as urban agglomerations, main roads, railways, and airports. These are complemented by ISO 1996-1:2016 and ISO 1996-2:2017 standards, which define the measurement and evaluation methods for environmental noise.

The LAeq,T represents the energy-averaged sound level over a specified time period, while Lmax indicates the highest instantaneous level recorded during that period. Percentile indicators such as L10 (exceeded 10% of the time) and L90 (background noise level) are sometimes used for transport noise characterization (EEA, 2019). Measurements are typically performed with Type 1 integrating sound level meters compliant with IEC 61672-1, at heights between 1.2–1.5 m above ground, and at standard distances from façades. Time-weighting settings, such as 'Fast' (125 ms) or 'Slow' (1 s), are applied according to the measurement objective.

While these methods provide valuable regulatory data, they offer limited spectral resolution. A-weighted levels tend to underrepresent low-frequency noise (below ~125 Hz), which can have significant physiological and psychological effects. Long-term studies have shown that the difference between unweighted or C-weighted levels (LCeq) and A-weighted levels (LAeq) can exceed 10 dB in urban environments with high low-frequency content (Asady et al., 2024; International Organization for Standardization, 2016). Furthermore, Schomer (2001) demonstrated that loudness-level weighting (LLSEL) correlates better with subjective annoyance than traditional A-weighting, particularly for transportation noise rich in low frequencies.

Given these limitations, summarized in Table 1, there is increasing support for incorporating full-spectrum measurements—capturing 1/3 octave or narrow-band data from 20 Hz to 20 kHz—into environmental assessment protocols. Such an approach improves the identification of dominant frequency bands, enabling the design of targeted mitigation measures.

Parameter/Method	Standard LAeq/Lmax Measurements	Full-Spectrum Analysis (1/3 octave)
Aggregated dB(A) value	Yes	Optional (can be A, C, or Z-weighted)
Frequency resolution	None	1/3 octave (20 Hz – 20 kHz)
Source identification	Limited	High (based on spectral signature)
Low-frequency detection (<125 Hz)	Poor (underrepresented)	Accurate
High-frequency analysis (>8 kHz)	Limited	Accurate
Direct mitigation guidance	General	Frequency-specific

Table 1. Parameters in standard vs. full-spectrum methods (Data from ISO 1996-1:2016 and Marusceac et al., 2022)

3. IMPORTANCE OF FULL-SPECTRUM ACOUSTIC MEASUREMENTS

Traditional A-weighted noise measurements, while suitable for regulatory reporting, often fail to identify the specific spectral components responsible for the most significant impacts on human health and comfort. This limitation is particularly evident in urban traffic environments, where different sources contribute to distinct frequency ranges. For example, rolling noise from tires generally dominates the low-frequency band (50–100 Hz), engine and powertrain noise tends to peak in the mid-frequency range (500–2000 Hz), and transient signals such as horns and sirens occupy the high-frequency range above 2 kHz (Haroon et al., 2022; Janusevicius & Akelaityte, 2015).

Full-spectrum acoustic analysis, using 1/3 octave or narrow-band resolution across 20 Hz–20 kHz, enables precise identification of these dominant bands. By doing so, it becomes possible to design mitigation measures specifically targeted at the problematic frequency range, thereby improving efficiency and cost-effectiveness. For example, low-frequency attenuation may require massive physical barriers, earth berms, or changes in urban geometry, whereas high-frequency noise can be reduced with lighter, porous materials (Picaut & Simon, 2001; Kang, 2002).

Case studies from Cluj-Napoca demonstrate the practical advantages of full-spectrum monitoring. Measurements conducted at major intersections revealed elevated noise levels in the 50–200 Hz band at signalized junctions, primarily due to repeated acceleration and braking cycles (Marusceac et al., 2022). In contrast, uncontrolled intersections with smoother traffic flow showed significantly lower energy in the same frequency range. This distinction would not be captured by LAeq measurements alone, as both intersection types displayed similar aggregated A-weighted levels.

Similarly, studies on traffic-calming devices found that certain types of speed breakers—particularly prefabricated plastic or rubber thresholds—produced substantial low-frequency peaks at 31.5 Hz and 63 Hz, with increases of up to 10 dB above baseline traffic noise (Marusceac et al., 2023). Asphalt-based speed humps, especially elongated designs, were found to generate less low-frequency noise but slightly more high-frequency content above 5 kHz, likely due to vehicle body and suspension resonance.

The relevance of this spectral differentiation extends beyond academic analysis; it directly informs engineering decisions. For example, in areas where low-frequency noise dominates, urban planners might prioritize physical separation between traffic corridors and residential buildings or use buffer zones with commercial or industrial functions. In cases of high-frequency dominance, façade treatments or vegetation barriers may suffice. Without full-spectrum data, such tailored interventions would be impossible to design with precision.

Furthermore, the World Health Organization (WHO, 2018) emphasizes that low-frequency noise, even at moderate A-weighted levels, can cause annoyance, sleep disturbance, and potential cardiovascular effects. Therefore, the underrepresentation of these frequencies in A-weighted measurements can lead to systematic underestimation of health risks (Asady et al., 2024; Schomer, 2001).

In summary, full-spectrum acoustic measurements not only enhance the accuracy of environmental noise assessment but also enable more effective, frequency-specific mitigation strategies. This approach aligns with modern urban planning objectives, which increasingly aim to integrate health-oriented acoustic design into the broader framework of sustainable city development.

4. APPLICATION EXAMPLES AND TARGETED MITIGATION SOLUTIONS

The value of full-spectrum acoustic measurements lies not only in their diagnostic capacity but also in their ability to inform targeted engineering and urban planning interventions. By analyzing frequency-specific patterns, noise mitigation strategies can be tailored to the dominant spectral components of the environment, thereby maximizing efficiency and cost-effectiveness.

4.1 Intersection Design and Traffic Flow Optimization

In Cluj-Napoca, comparative spectral measurements at three intersection types — roundabout, Figure 2, signalized, Figure 3 and uncontrolled, Figure 4 — revealed that while aggregated LAeq values were similar, the spectral profiles differed significantly. Signalized intersections exhibited pronounced energy in the 50–200 Hz range, driven by acceleration and braking cycles, whereas roundabouts and uncontrolled junctions showed reduced low-frequency peaks due to smoother traffic flow (Marusceac et al., 2022).

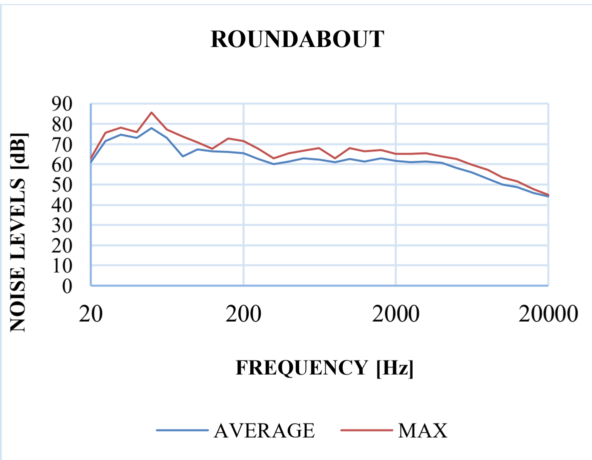

Figure 2. Average full-spectrum noise levels at a roundabout intersection. Adapted from (Marusceac et. al., 2022, Fig. 5)

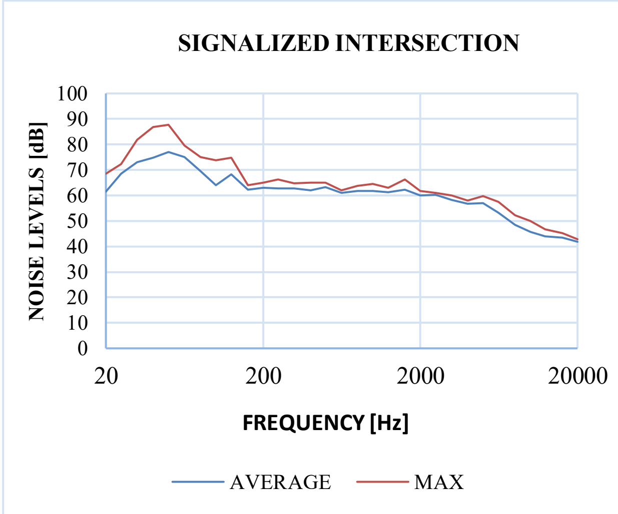

Figure 3. Average full-spectrum noise levels at a signalized intersection. Adapted from (Marusceac et. al., 2022, Fig. 5)

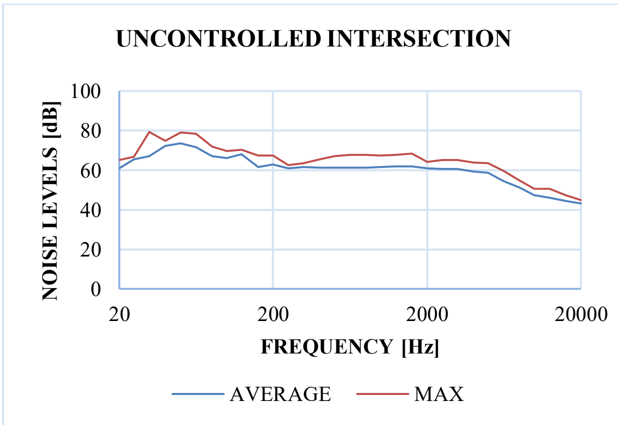

Figure 4. Average full-spectrum noise levels at an uncontrolled intersection. Adapted from (Marusceac et. al., 2022, Fig. 5)

4.1.1 Mitigation strategy: Minimizing unnecessary stops and accelerations through adaptive signal control or traffic calming designs that preserve flow can substantially reduce low-frequency noise. Where such control is impractical, physical buffers or land-use zoning can be applied to shield residential façades from direct exposure.

4.2 Impact of Traffic-Calming Devices

Studies on speed breakers demonstrated that material and geometry influence the spectral distribution of noise, Figure 5. Prefabricated plastic/rubber thresholds produced strong low-frequency peaks at 31.5 Hz and 63 Hz, with increases of up to 10 dB above baseline traffic levels, while elongated asphalt humps resulted in lower low-frequency emissions but a modest increase in high-frequency content above 5 kHz (Marusceac et al., 2023).

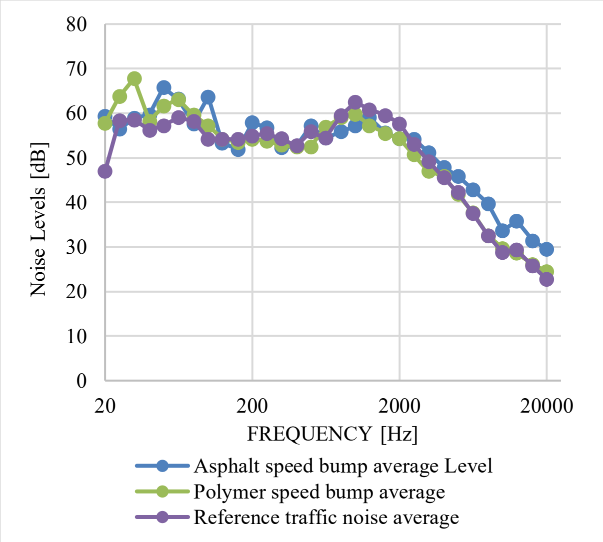

Figure 5. Full-spectrum comparative noise levels for polymer and asphalt speed breakers, showing their peaks at low frequencies (Adapted from Marusceac et al., 2023)

4.2.1 Mitigation strategy: In areas where low-frequency control is critical, asphalt humps or alternative traffic-calming designs (e.g., chicanes) should be preferred over plastic thresholds. For high-frequency mitigation, surface treatments and regular maintenance to prevent rattling vehicle components can be effective.

4.2.2 Positive Safety Impacts of Speed Control Measures: While certain traffic-calming devices, such as prefabricated plastic speed breakers, can increase low-frequency noise levels, their implementation may nonetheless yield substantial road safety benefits. Local accident data from Cluj-Napoca, Romania, show a marked reduction in collision frequency and injury severity following the installation of speed breakers in residential and school-adjacent streets (Cluj-Napoca Police Department, 2022). This trend is consistent with broader international evidence: a meta-analysis by Elvik (1997) found that speed humps and similar devices reduce injury crashes by an average of 44%, with the most pronounced effects observed in areas with high pedestrian activity. These safety benefits are aligned with the European Union's Road Safety Policy Framework 2021–2030, which promotes the adoption of a default 30 km/h speed limit in most urban streets to reduce traffic fatalities and serious injuries, particularly among vulnerable road users (European Commission, 2021). Integrating such speed management policies with targeted noise mitigation strategies could therefore provide a holistic approach to urban mobility, maximizing public health benefits while minimizing acoustic drawbacks.

4.3 Urban Morphology and Building Placement

Urban form strongly affects noise propagation. Research shows that street canyons with reflective façades can trap and amplify mid- and high-frequency components, whereas strategic building placement can shield quieter zones behind them (Picaut & Simon, 2001; Kang, 2002). In Cluj-Napoca, high-rise buildings along Fabricii Street acted as effective barriers, reducing noise levels by up to 15 dB in protected areas behind them (Marusceac & Ciotlaus, 2019).

4.3.1 Mitigation strategy: Planning buffer zones of non-residential, acoustically robust buildings along major traffic corridors can serve dual purposes—noise shielding and functional urban development.

4.4 Source-Specific Mitigation Examples

Full-spectrum analysis facilitates targeted solutions, Table 6, such as:
- Low-frequency dominance (e.g., heavy vehicles, speed breakers): Use of massive barriers, earthen berms, or rerouting heavy traffic; improving suspension and tire design (Yamada, 1993).

- Mid-frequency dominance (e.g., engines, mechanical systems): Promotion of electric or hybrid vehicles, improved exhaust systems.

- High-frequency dominance (e.g., sirens, horns): Use of directional siren technologies, façade soundproofing with lightweight absorptive materials.

Dominant Frequency Range	Common Sources	Health /Perception Effects	Recommended Mitigation
<125 Hz (Low)	Heavy vehicles, speed breakers, HVAC	Annoyance, sleep disturbance, vibration	Massive barriers, berms, rerouting, suspension design
125–2000 Hz (Mid)	Engines, exhaust, industrial fans	Annoyance, speech interference	Quieter engines, hybrid/electric transition, mufflers
>2000 Hz (High)	Horns, sirens, brakes	Sharpness, startle, hearing damage (long-term)	Directional alarms, façade insulation, vegetation screens

Table 6. Targeted mitigation strategies by dominant frequency range. Adapted from (WHO, 2018, Picaut & Simon, 2001, Kang, 2002)

4.5 Policy Integration

For urban noise management to be effective, spectral analysis should be integrated into noise mapping and action plan development mandated by the Environmental Noise Directive (Directive 2002/49/EC). Current mapping practices largely rely on A-weighted averages, which may misrepresent exposure risks for specific populations, especially in low-frequency-dominated environments (WHO, 2018; Asady et al., 2024).

5. CONCLUSIONS

This study underscores the critical limitations of traditional A-weighted environmental noise measurements in accurately representing the spectral complexity of urban soundscapes. While parameters such as LAeq and Lmax remain essential for regulatory compliance, they fail to capture frequency-specific characteristics that directly influence human perception, health impacts, and the efficiency of mitigation measures.

Through the integration of full-spectrum acoustic measurements—covering the 20 Hz to 20 kHz range in 1/3 octave bands—it becomes possible to identify dominant noise components and their corresponding sources with precision. Case studies from Cluj-Napoca demonstrate that:

- Signalized intersections produce significant low-frequency peaks (50–200 Hz) due to acceleration and braking cycles, while uncontrolled intersections exhibit reduced energy in this range due to smoother traffic flow.

- Prefabricated plastic/rubber speed breakers generate strong low-frequency peaks (31.5 Hz and 63 Hz), while elongated asphalt humps exhibit lower low-frequency noise but can introduce modest high-frequency components.

- Urban morphology, particularly the strategic placement of high-rise or non-residential buildings along major traffic corridors, can achieve reductions of up to 15 dB in protected areas, depending on façade materials and geometry.

The implications of these findings are twofold. First, integrating spectral analysis into the framework of the Environmental Noise Directive (Directive 2002/49/EC) and ISO 1996 standards would enhance the accuracy of noise mapping and exposure assessment, especially in environments where low-frequency noise is prevalent. Second, frequency targeted mitigation whether through urban design, material selection, traffic management, or vehicle technology can yield more effective and resource efficient outcomes.

Future work should focus on:
- Developing standardized protocols for incorporating full-spectrum data into regulatory reporting.
- Expanding the use of mobile and continuous spectral monitoring in urban noise studies.
- Investigating the combined effects of spectral noise characteristics and psychoacoustic parameters (e.g., loudness, sharpness) on community response.

By adopting a frequency-aware approach to environmental noise assessment, urban planners, engineers, and policymakers can better address both the objective and subjective dimensions of acoustic comfort, ultimately contributing to healthier and more sustainable urban environments.

References

Asady, H., et al. (2024). Why A-weighting is inadequate for measurement of noise with high content of infrasound and low frequency noise (ILFN). *Proceedings of the Institute of Acoustics*, 46(2), https://www.ioa.org.uk/system/files/publications/H%20ASADY%20et%20al%20WHY%20A-WEIGHTING%20NETWORK%20IS%20INADEQUATE%20FOR%20MEASUREMENT%20OF%20NOISE%20WITH%20HIGH%20CONTENT%20OF%20INFRASOUND%20AND%20LOW%20FREQUENCY%20NOISE%20%28ILNF%29.pdf.

Cluj-Napoca Police Department. (2022). Annual traffic accident report. Cluj-Napoca, Romania.

Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise. *Official Journal of the European Communities*, L 189, 12–25.

EEA (European Environment Agency). (2019). Environmental noise in Europe — 2020 (EEA Report No. 22/2019). Publications Office of the European Union. https://doi.org/10.2800/686249.

Elvik, R. (1997). Effects on accidents of automatic speed enforcement in Norway. *Transportation Research Record*, 1595(1), 14-19. https://journals.sagepub.com/doi/10.3141/1595-03.

European Commission. (2021). EU road safety policy framework 2021–2030 – Next steps towards "Vision Zero". https://transport.ec.europa.eu/.

Haroon, M. J., Kharbeche, M., Alhajyaseen, W., & Alhawari, A. (2022). Impact of speed hump on noise pollution. Australasian Transport Research Forum Proceedings. https://trid.trb.org/View/2259733.

International Organization for Standardization. (2016). ISO 1996-1:2016 Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment procedures. ISO.

Janusevicius, T., & Akelaityte, R. (2015). Speed bumps impact on motor transport noise. *The Baltic Journal of Road and Bridge Engineering*, 10(2), 191–199. https://doi.org/10.3846/bjrbe.2015.23.

Kang, J. (2002). Numerical modelling of sound fields in urban streets with diffusely reflecting boundaries. *Journal of Sound and Vibration*, 258(5), 793–813. https://doi.org/10.1006/jsvi.2002.5164.

Marusceac, V., & Ciotlaus, M. (2019). Optimizing urban landscapes in regard to noise pollution. *Procedia Manufacturing*, 32, 161–166. https://doi.org/10.1016/j.promfg.2019.02.200.

Marusceac, V., Danciu, A., Ciotlaus, M., & Dragomir, M. (2022). Impact of non-structural road elements on noise pollution: A case study in Cluj-Napoca, Romania. In *Interdisciplinarity in Engineering* (Vol. 605, pp. 47–56). Springer. https://doi.org/10.1007/978-3-031-12053-1_6.

Marusceac, V., Danciu, A., Ciotlaus, M., & Dragomir, M. (2023). Influence of speed breakers on traffic-generated noise levels. *Journal of Applied Engineering Sciences*, 13(26), 253–258. https://doi.org/10.2478/jaes-2023-0025.

Passchier-Vermeer, W., & Passchier, F. W. (2000). Noise exposure and public health. *Environmental Health Perspectives*, 108(Suppl 1), 123–131. https://doi.org/10.1289/ehp.00108s1123.

Picaut, J., & Simon, L. (2001). A scale model experiment for the study of sound propagation in urban areas. *Applied Acoustics*, 62(3), 327–340. https://doi.org/10.1016/S0003-682X(00)00030-1.

Schomer, P. D. (2001). On normalizing community response to noise: The effect of different noise metrics and weighting functions. *Journal of the Acoustical Society of America*, 110(1), 239–245. https://doi.org/10.1121/1.1371763.

WHO (World Health Organization). (2018). Environmental noise guidelines for the European region. WHO Regional Office for Europe. https://www.who.int/europe/publications/i/item/9789289053563

Yamada, H. (1993). On the influence of tire characteristics on tire noise. JSAE Symposium, 9301, 38–43.