forum acusticum 2026
8-12 September · Graz, Austria

ACOUSTIC EFFECTIVENESS OF THE NOISE BARRIER: EVIDENCE FROM A PHASED CONSTRUCTION THROUGH A MULTI-METRIC ASSESSMENT

Qiuya Xiang[1], Ablenya Barros[1], Cedric Vuye[1]
[1]*Faculty of Applied Engineering, University of Antwerp, Belgium*

Abstract

Noise barriers have been widely constructed as a common measure for mitigating road traffic noise. However, their effectiveness has often been evaluated primarily in terms of sound pressure level reduction, using $L_{Aeq,15\ min}$, and the estimated reduction using simulated values, with less attention given to other acoustic characteristics or long-term performance. To address this gap, this study investigates the acoustic characteristics along a national road before, during, and after noise barrier construction over six months at 20 measurement locations, including noise levels, noise events, and Artificial Intelligence estimated sound sources. The measurement locations were grouped by distance from the main road to assess the spatial effectiveness of the barriers. By comparing phased measurements across locations and periods, with additional analysis of temporal variations, specifically between daytime and nighttime and between workdays and non-workdays, this study identifies how the barrier influenced different dimensions of the acoustic environment beyond simple attenuation. The findings provide empirical support for traffic noise mitigation strategies and suggest that the effectiveness of noise barriers can be more comprehensively understood by considering a multi-metric acoustic assessment in broader soundscape characteristics.

Keywords: *road traffic noise, noise barrier, multi-metric assessment, phased construction*

1. Introduction

Road traffic noise is one of the dominant environmental noise sources in urban areas, particularly along roads where high traffic volume and vehicle speed contribute to persistent noise exposure that causes public health problems [1]. Emphasizing this issue, the European (EU) authorities published the Environmental Noise Directive (END) in 2002 [2], which requires every 5 years the development of subsequent action plans to mitigate noise for major agglomerations and key infrastructures [3]. Noise barriers, as a noise mitigation method, are commonly used as a practical obstacle to reduce the propagation of traffic noise towards nearby residential areas so as to improve the acoustic environment. As a result, the noise exposure can be reduced by 5–15 dB depending on the barrier height, the source-receiver relative position and the wind direction [4]. Accordingly, to evaluate the effectiveness of noise barriers under real conditions, appropriate acoustic indicators are required to describe the difference before and after barrier implementation.

The indicators commonly used include equivalent or aggregated sound levels, such as L_p, $L_{Aeq,\ T}$, L_{max}, over short time periods (from 30 minutes to 24 hours) before and after the installation, and frequency content (e.g., split in octave bands) [5]. These indicators provide a standardised and quantifiable description of acoustic exposure. However, traffic noise is often experienced through repeated and salient events, such as vehicle pass-bys or high-level peaks, which are not fully represented by loudness [6]. In addition, changes in the relative dominance of sound sources may alter the character of the sound environment even when average levels change only moderately [7]. Apart from this, the before-after comparison misses the possible effects caused by the construction of the barriers, which contribute to a new noise source [8].

Besides, the acoustic environment also varies across space and time. Locations close to the road benefit more directly from acoustic shielding, whereas the effect is limited beyond 150 meters [9]. Similarly, because of the changes in traffic volume, vehicle speed, background

Corresponding author: *qiuya.xiang@uantwerpen.be.*

levels and human activities, the acoustic effect of a barrier may differ temporally [10]. Based on these facts, a phased construction process provides a useful empirical opportunity to observe acoustic changes over time. It helps to reveal whether changes occur gradually and temporarily.

This study aims to investigate the acoustic effectiveness of noise barriers constructed along a national road by using long-term measurements at surrounding residences. The study compares acoustic conditions before, during, and after installation and integrates multiple indicators. The results provide empirical evidence and critical insights into the real-world phased construction conditions, aiming at offering guidance for future assessment of interventions.

2. Methodology

2.1 Study area with noise barriers

The measurement was taken in Aalter, a municipality in the Belgian province of East-Flanders, where a new noise barrier was installed along the N44 national road, as shown in Fig. 1. The noise barriers in the study area were prefabricated concrete elements. Each standard panel measures 1 m in height and 5 m in length. The barriers consist of reinforced precast concrete panels fitted on one or both sides with sound-absorbing and wood fibre concrete cladding of the Faseton Hohlwelle type, with an absorber thickness of 12 cm [11].

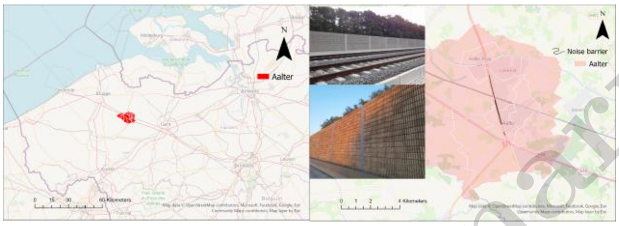

Figure 1. (left)Location of study area, (middle) new noise barriers and (right) N44 national road.

2.2 Measurement locations

As part of the citizen science project "De Oorzaak", 20 citizen scientists were recruited as participants by the Flemish Agency for Roads and Traffic (AWV), all of whom lived within 200 meters of the construction site of noise barriers on the N44 national road. The citizen scientists were asked to install a smart sound sensor against their façade, clamped on the window sill using a mounting bracket, see Fig. 2. To examine the influence of distance from the national road on noise levels, the 20 locations were grouped into three distance bands according to their shortest distance to the road centerline: ≤50 m, 50–100 m, and >100 m. This grouping was used to compare the spatial variation of acoustic indicators across locations with different levels of road noise exposure.

Figure 2. Locations of measurement points (left) and installation details (middle and right).

2.3 Data collection

The acoustical data is collected by smart sensors of type NP9 by Munisense, The Netherlands. They were each equipped with a Class II microphone and an AI model that was able to recognize 9 different classes of sound sources, as shown in Fig.2. The data was transmitted via the Orange network in Belgium to the researchers' database and to each participant's personal dashboard. In this way, we gained a "real-time" understanding of the sounds people heard and their sound pressure levels.

2.4 Timeline

The duration of measurement is about seven months, covering the full installation of noise barriers and approximately a month before and after. Based on the stages of barrier construction, the timeline is divided into four phases, including Pre, A, B, and Post phases, depending on the installation stage of barriers. See Table 1 below for details.

Table 1. Timeline of measurement and construction.

Time	Starting Phase	Event	Speed limit
01/05/2024	Pre	Start measurement	90 km/h
27/05/2024	A	Start the installation of noise barriers West	50 km/h
09/07/2024		End of installation	90 km/h
06/08/2024	B	Start the installation of noise barriers East	50 km/h
14/10/2024		Extend noise barriers south of island	90 km/h
08/11/2024	Post	End of installation	90 km/h
09/12/2024	End Post	End of measurement	90 km/h

2.5 Data analysis

The effectiveness of noise barriers has often been quantified in terms of the reduction in sound pressure levels, or insertion loss, by comparing the measured noise levels before and after barrier construction under comparable traffic and meteorological conditions [6]. Therefore, this study uses noise levels, noise events and noise sources to explain the acoustic environment. There are five indicators used to describe noise levels. L_{den} represents the day-evening-night A-weighted equivalent sound level, incorporating penalties for evening and nighttime periods, with L_{day} and L_{night}

describing the daytime (7-19) and nighttime (23-7) performance, respectively [2]. L_{A95} and L_{A05} represent the A-weighted sound levels exceeded for 95% and 5% of the measurement period [12]. In this study, L_{A95} was used as a proxy for the background sound level, while L_{A05} was used to indicate high-level noise conditions associated with prominent noise events.

In addition, some studies have examined changes in noise events that focus more on sudden, high-intensity sounds occurring over a short period of time that impact people's subjective perceptions and the disruption [13]. In this study, we define "noise events" by using the A-weighted equivalent noise level $L_{Aeq,1s}$ and compare this value with the moving average over 15 minutes, $L_{Aeq,\ 15min.,m}$. If the difference is larger than 10 dBA, it is considered a noise event as in Eq. (1). As a result, the number of noise events in decibels of their peak levels is used as an indicator to examine the occurrence of sudden sound.

$$L_{Aeq,1s} > L_{Aeq,15min.,m} + 10\ dB(A) \tag{1}$$

A threshold of 70 dB was used to distinguish loud events from quiet events. The U.S. Federal Highway Administration uses L10(h) = 70 dB as one of the noise abatement criteria for residential and other noise-sensitive outdoor areas [14]. In addition, event-based noise metrics such as NA70 or N70 have been used in previous noise studies to describe the number of events exceeding 70 dB [15]. Therefore, based on the LAmax of the noise events, they are categorized by 5 dB and divided into two groups: "Loud events" (>70 dB) and "Quiet events" (≤70 dB) in this study.

Moreover, all noise events (starting from period XX) were labelled by the AI algorithm developed in the De Oorzaak project, based on the Mel spectrogram [16]. This study uses an AI model from ASAsense trained using open-source datasets such as Google AudioSet, supplemented with samples collected and labelled during De Oorzaak. It enabled the identification of specific noise events with a specified level of certainty, as well as the determination of their occurrence, intensity, and duration at a temporal resolution of one second. According to the sound categorization scheme and commonly occurring sound sources [17], events are classified using a certainty of 50% into nine categories: road traffic, air traffic, rail traffic, nature, building works, alarms and sirens, humans, abrupt sound, and pets. To more directly describe the noise events labelled, the "noise source" is used instead in this study.

3. Results

3.1 Sample characterization

To ensure the data used for analysis is accurate, valid, consistent, and comparable, missing or invalid samples were excluded due to incomplete recordings, equipment malfunction and localized extreme events. Finally, there are 17 valid sensors in the pre phase, 20 in both phases A and B, and 16 valid ones in the post phase.

3.2 Overall phased variation

The phased comparison shows how the acoustic environment evolved during the construction process. The pre phase represented the baseline condition, while phases A and B reflected a transitional acoustic environment affected by partial barrier completion, reduced speed limit and additional construction noise. The post phase was therefore the main reference for evaluating the completed barrier effect against the baseline condition.

3.2.1 Noise levels

As the data shows in Fig. 3, a preliminary comparison of the level-based indicators suggests a consistent reduction in environmental noise exposure after the construction of the noise barriers. Specifically, L_{den} decreased from 62.1 dB before construction to 56.3 dB after completion, corresponding to a decrease of 4.8 dB. A similar pattern was observed for L_{day}, which declined from 59.3 to 54.6 dB, indicating a 4.7 dB reduction. L_{night} also decreased from 53.0 to 48.2 dB, with a reduction of 4.9 dB. As expected, the change in L_{A95} is relatively small, decreasing slightly from 39.6 dB before construction to 38.7 dB after completion, with a reduction of only about 0.9 dB. By comparison, L_{A05}, which reflects the upper range of the noise level distribution, decreases more substantially from 62.3 to 57.2 dB, corresponding to a reduction of about 5.1 dB. Furthermore, when considering changes across the construction phases, several indicators reach lower levels during phase B, most likely due to the lower speed limit, whilst the figures rise slightly after completion.

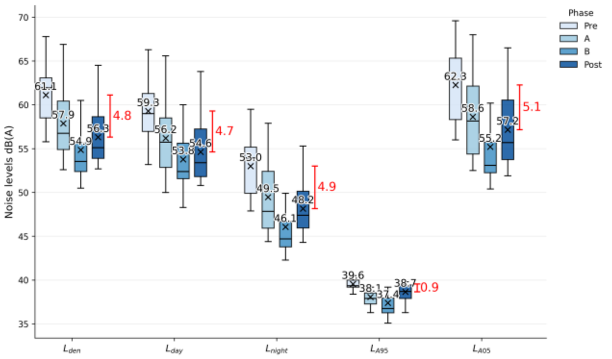

Figure 3. Average L_{den}, L_{day}, L_{night}, L_{A95}, L_{A05} in four phases.

3.2.2 Noise events

Fig. 4 shows the variation in the average number of noise events per day across each construction phase, summing from all valid sensors. The median number of total events decreased from 303.8 times before construction to 195.7 times after construction, corresponding to a reduction of 113.1 events. Loud events also showed a marked decrease, from 73.8 times in the pre phase to 32.5 times in the post-construction phase. The largest reduction in loud events occurred between the pre-construction phase and phase A, after which the values remained relatively low. Quiet events decreased more gradually, from 235.1 times before construction to 163.1 times after construction, with intermediate values of 226.7 and 213.0 in phases A and B, respectively.

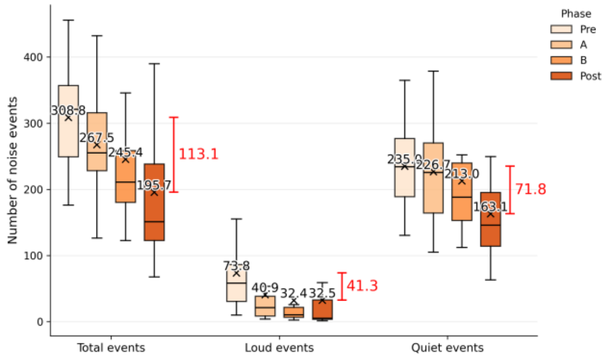

Figure 4. Average number of total, loud and quiet noise events of four phases.

3.2.3 Noise sources

The averaged duration (seconds) per day of AI-estimated noise source composition across phases A, B, and post is illustrated in Fig. 5. No valid result was available for the pre phase as the Mel spectrograms were not saved at that time due to a technical issue. Regarding the proportion of noise sources, road traffic remained the dominant sound source across all available phases, accounting for nearly or more than half of the total recorded duration in each case: 57.4% in A, 48.3% in B, and 53.6% in post phase. In terms of cumulative event duration, the total duration of classified noise events decreased from 445.4 s during Phase B to 299.9 s after construction. Road traffic, as the dominant source, decreased from 215.1 s to 160.7 s. Building works also decreased in absolute duration, from 66.8 s to 48.8 s. However, their relative contribution to the overall source composition increased slightly after construction. Further analysis should consider the loudness of different noise sources and their temporal distribution across the day.

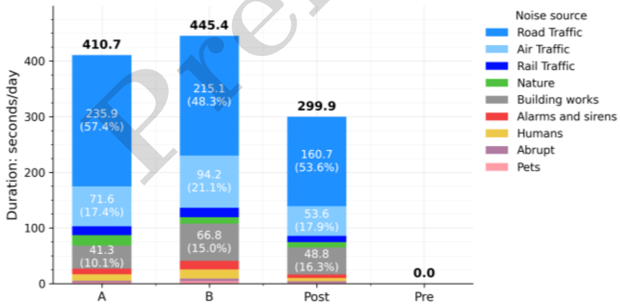

Figure 7. Average duration and proportion of noise sources in four phases.

3.3 Spatial patterns

The spatial maps shown in Fig. 6 indicate that higher noise levels were generally concentrated along the national road corridor. The reduction in L_{den} is more pronounced at locations closer to the N44 road than at those more than 100 m away, with reductions ranging from 2.1 to 9.7 dB.

To further examine this distance-related pattern, the measurement locations were grouped by their distance from the national road. The grouped results in Fig. 7 indicate that the locations within 50 m generally recorded the highest values of L_{den}, L_{day}, and L_{night}, whereas locations more than 100 m from the road tended to exhibit lower noise levels, particularly during the nighttime. The number of noise events decreased after the barrier construction across all distance groups. This reduction was most evident in the ≤50 m group, where the cumulated number of noise events dropped from 331.0 to 152.0, and in the 50–100 m group, where it decreased from 359.2 to 227.6. The >100 m group showed a smaller reduction, from 207.2 to 168.9.

Figure 5. Maps of L_{den} in pre (left), post (middle) phases and the pre-post difference.

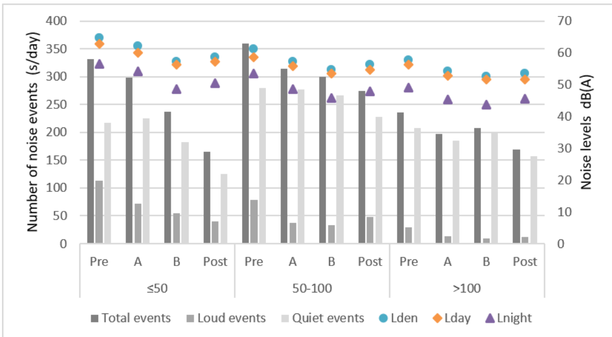

Figure 6. Average number of total, loud and quiet noise events with L_{den}, L_{day}, L_{night} of four phases in three distance groups.

3.4 Temporal variation

3.4.1 Day-Night

According to Fig. 8, the noise levels in terms of L_{day} and L_{night} both decreased in the post phase compared to the pre phase. During the daytime, participants are exposed to higher noise than at night, with a 5.6 dB difference on average. The day–night comparison of noise sources shows clear temporal differences in source composition. Road traffic remained the dominant source category in both daytime and nighttime periods, but its relative and absolute contribution was generally higher at night. This is related to the fact that during the day, there is more traffic contributing to a higher moving average and fewer noise events, whereas during the night, most likely, almost every passing vehicle triggers a noise event. Air traffic also had a stronger nighttime contribution, particularly in the post phase. In contrast, building works and human sound were more prominent during the daytime, reflecting activity-related sound sources.

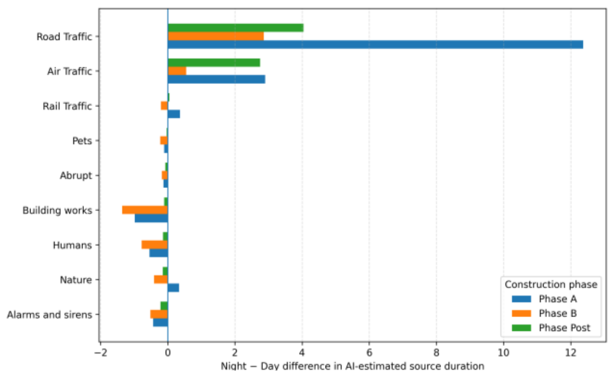

Figure 8. Difference of duration of noise sources average per day between day and night.

3.4.2 Workday-Holiday

The pre–post comparison by day type showed reductions in all sound level indicators for both workdays and non-workdays in Fig. 9. On workdays, the reduction ranged from 0.6 dB for L_{A95} to 5.3 dB for L_{night}. On non-workdays, the reduction ranged from 1.0dB for L_{A95} to 5.0 dB for L_{night}. The reductions were generally larger on workdays, particularly for L_{A05}, suggesting that the barrier effect was more evident under regular weekday traffic conditions. In contrast, L_{A95} showed only limited reductions for both day types.

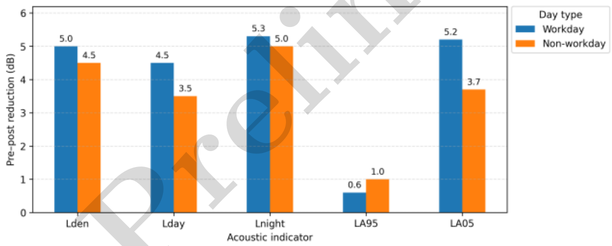

Figure 9. Difference of noise levels between pre and post phases in workday and non-workday.

4. Discussion

The multi-metric results provide a general reduction in the eventfulness of the acoustic environment, as reflected by decreases in total, loud, and quiet noise events, together with a shorter duration of road traffic noise. This indicates that the barrier effect was more clearly expressed through changes in road traffic events than through a uniform decrease in level-based indicators.

The general sound-level indicators reveal that the noise barrier influenced the acoustic environment unevenly. The larger reduction in L_{A05} than in L_{A95} suggests that the barrier was more effective in attenuating high-level noise events. The limited change in $L_{A95,}$ therefore, indicates the marginal effect on background acoustic environment. Besides, the rebound of sound level indicators in the post phase compared with phase B should be interpreted in relation to changes in traffic conditions. Important information was that the speed limit on the N44 had been lowered to 50 km/h in phase B and returned to 90 km/h in the post phase. Previous research has found that higher vehicle speeds have increased tyre road noise [18]. This may explain why phase B shows lower sound levels than the post phase.

The results also show that barrier performance was context dependent. Temporally, the nighttime sound environment was more strongly dominated by transport-related sources, particularly road traffic and air traffic, while daytime included a broader mixture of traffic, construction, and human activity sounds. Spatially, locations closer to the N44 showed more direct reductions, while more distant locations appeared to be more influenced by local sound sources, building reflections, and propagation conditions.

In summary, these findings imply that noise barrier assessment should combine level-based, event-based, and source-based indicators, providing a more comprehensive understanding of barrier effectiveness. Several limitations should be noted, including the variations in traffic speed and volume, meteorological variability, and the absence of valid source classification data in pre phase.

5. Conclusion

This study evaluated the acoustic effectiveness of a newly constructed noise barrier using a six-month phased measurement approach. Overall, the noise barrier plays a role in reducing noise levels by around 5 dB, although the changes were not monotonic across all phases. It further indicates that barrier performance was spatially and temporally dependent. Locations closer to the road showed clearer reductions. Besides, this study highlights the value of combining indicators that describe loudness, eventfulness and context. Event metrics captured reductions in total and loud noise events, while AI-estimated source classification indicated shorter road traffic noise durations. These indicators complement conventional insertion-loss assessment by better reflecting short-term variation and auditory experience.

Despite these findings, the study is limited by the relatively small number of measurement locations and the absence of perceptual data. Future work should combine residents' perceptions, such as noise annoyance responses, to better understand how measured barrier effects translate into experienced soundscape improvements.

6. Acknowledgments

This research is a part of the project "*De Oorzaak*". The authors would like to thank the 20 citizen scientists willing to install a sound sensor on their façade. Additionally, we are grateful to the Flemish Agency for Roads and Traffic (AWV) for their assistance in this research (access to the measurement timeline, information on noise barriers, and recruitment of participants and distribution of sensors).

References

[1] J. Hegewald, M. Schubert, A. Freiberg, K. Romero Starke, F. Augustin, S. G. Riedel-Heller, H. Zeeb, and A. Seidler, "Traffic noise and mental health: A systematic review and meta-analysis," *International Journal of Environmental Research and Public Health*, vol. 17, no. 17, Art. no. 6175, 2020, doi: 10.3390/ijerph17176175.

[2] European Parliament and Council of the European Union, "Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise," *Official Journal of the European Communities*, vol. L 189, pp. 12–25, Jul. 18, 2002.

[3] G. Licitra, E. Ascari, and L. Fredianelli, "Prioritizing process in action plans: A review of approaches," *Current Pollution Reports*, vol. 3, no. 2, pp. 151–161, 2017, doi: 10.1007/s40726-017-0057-5.

[4] T. Van Renterghem and D. Botteldooren, "On the choice between walls and berms for road traffic noise shielding including wind effects," *Landscape and Urban Planning*, vol. 105, no. 3, pp. 199–210, 2012, doi: 10.1016/j.landurbplan.2011.12.017.

[5] International Organization for Standardization, *ISO 10847:1997, Acoustics—In-situ determination of insertion loss of outdoor noise barriers of all types*. Geneva, Switzerland: ISO, 1997.

[6] B. Schäffer, A. Taghipour, J. M. Wunderli, M. Brink, L. Bartha, and S. J. Schlittmeier, "Does the macro-temporal pattern of road traffic noise affect noise annoyance and cognitive performance?" *International Journal of Environmental Research and Public Health*, vol. 19, no. 7, Art. no. 4255, 2022, doi: 10.3390/ijerph19074255.

[7] Z. U. R. Farooqi, I. Ahmad, A. Ditta, P. Ilic, M. Amin, A. B. Naveed, and A. Gulzar, "Types, sources, socioeconomic impacts, and control strategies of environmental noise: A review," *Environmental Science and Pollution Research*, vol. 29, no. 54, pp. 81087–81111, 2022, doi: 10.1007/s11356-022-23328-7.

[8] M. Mir, F. Nasirzadeh, H. Bereznicki, P. Enticott, and S. Lee, "Investigating the effects of different levels and types of construction noise on emotions using EEG data," *Building and Environment*, vol. 225, Art. no. 109619, 2022, doi: 10.1016/j.buildenv.2022.109619.

[9] J. Kastka, E. Buchta, U. Ritterstaedt, R. Paulsen, and U. Mau, "The long term effect of noise protection barriers on the annoyance response of residents," *Journal of Sound and Vibration*, vol. 184, no. 5, pp. 823–852, 1995, doi: 10.1006/jsvi.1995.0348.

[10] K. Abdur-Rouf and K. Shaaban, "Measuring, mapping, and evaluating daytime traffic noise levels at urban road intersections in Doha, Qatar," *Future Transportation*, vol. 2, no. 3, pp. 625–643, 2022, doi: 10.3390/futuretransp2030034.

[11] Omnibeton nv, *Technische fiche FASETON HOHLWELLE: Geluidswanden met hoogabsorberend houtvezelbeton*. Hasselt, Belgium: Omnibeton nv, Jan. 6, 2020.

[12] International Organization for Standardization, ISO 1996-1:2016, *Acoustics—Description, measurement and assessment of environmental noise—Part 1: Basic quantities and assessment procedures*. Geneva, Switzerland: ISO, 2016.

[13] N. Antanuri and S.-K. Lau, "Effects of noise events and temporal variability in road traffic noise on perceived acoustic environment and cognitive performance," *Building and Environment*, vol. 289, Art. no. 114012, 2026, doi: 10.1016/j.buildenv.2025.114012.

[14] Federal Highway Administration, U.S. Department of Transportation, "Procedures for Abatement of Highway Traffic Noise and Construction Noise," 23 CFR Part 772, Appendix Table 1 to Part 772—Noise Abatement Criteria, *Code of Federal Regulations*, Title 23.

[15] European Commission, *Sound Noise Limits: Options for a Uniform Noise Limiting Scheme for EU Airports*. Brussels, Belgium: European Commission, Jan. 2005.

[16] C. Vuye, et al.: *De Oorzaak: Wetenschappelijk eindrapport* (in Dutch), Univ. of Antwerp, Antwerp, Belgium, 2026, 207 pages.

[17] J. K. A. Tan, Y. Hasegawa, and S.-K. Lau, "A comprehensive environmental sound categorization scheme of an urban city," *Applied Acoustics*, vol. 199, Art. no. 109018, 2022, doi: 10.1016/j.apacoust.2022.109018.

[18] J. Winroth, S. Kropp, and W. K. W. Lau, "Investigating generation mechanisms of tyre/road noise by speed exponent analysis," *Applied Acoustics*, vol. 115, pp. 101–108, 2017, doi: 10.1016/j.apacoust.2016.08.016.