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Research Article

Evaluation of an Aluminum Noise Barrier on the Reduction of Railway Noise

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Abstract: Railway noise barriers are widely used to mitigate environmental noise in cases where source-based noise reduction measures are insufficient to satisfy regulatory limit values. In this study, the effectiveness of an aluminum railway noise barrier was investigated for residential areas located near Arifiye Train Station in Türkiye. Environmental noise measurements and strategic noise maps were prepared to evaluate railway noise exposure in the study area. The results indicated that environmental noise levels measured near the railway corridor exceeded the applicable regulatory limits. Therefore, an aluminum railway noise barrier was designed and optimized considering site-specific geometric and operational constraints. Simulation results obtained before and after noise barrier installation were comparatively evaluated. According to the simulation results, the daily average environmental noise levels at residential areas close to the railway were predicted to decrease below the regulatory limit values after barrier installation. In addition to overall daily average noise levels, daytime, evening, and nighttime noise measurements were also assessed. Furthermore, noise reductions at the ground and first floors of residential buildings were comparatively analyzed, demonstrating higher noise attenuation at ground-floor receiver locations. Post-installation field measurements confirmed that the proposed barrier system effectively reduced railway noise levels under real operating conditions. The study contributes to the literature by providing an integrated assessment framework combining field measurements, simulation-based optimization, and post-installation validation for railway noise mitigation applications.

Keywords: *Intercity railway, Environmental noise, Railway noise, Noise barrier*

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I. INTRODUCTION

Many activities in daily life cause environmental effects. Although there are many sources of noise, transportation-related noise is among the major environmental factors negatively affecting human and public health (World Health Organization, 2018). Traffic noise is one of the most important environmental impacts that have negative effects on society (Gupta & Ghatak, 2011; World Health Organization, 2018). According to recent European Environment Agency (EEA) reports, more than 110 million people in Europe are exposed to transport noise levels considered harmful to human health and well-being (EEA, 2025). Noise has physical such as increased heart rate, arrhythmia, hypertension and psychological effects such as stress, psychological disorders, irritability, difficulty sleeping etc. on people (Muzet, 2007). The importance of rail systems is increasing day by day for a faster, safer, more comfortable, less energy consuming and more environmentally friendly transportation system and its use is rapidly spreading worldwide (Yang et al., 2016). According to UIC data, when comparing rail passenger and freight transportation metrics between 2004 and 2024, it is observed that the passenger-kilometer value increased by approximately 75%, with the ton-kilometer value also rising by about 38% (UIC, 2024). With the increase of rail transport, railway-induced noise emerges as a problem that requires effective mitigation measures (Wosniacki & Zannin, 2021). An estimated 18 million individuals in Europe are exposed to railway noise levels considered harmful to human health and well-being (EEA, 2025). In this context, it is essential to take measures to minimize the effects of railway-related noise for people living near the railway as well as for passengers using the rail system (Moritoh et al., 1996).

Since rail systems are operated on certain routes, they do not cause as much noise as highway transportation (Gupta & Ghatak, 2011). Passengers using these systems and people residing near railway corridors are affected by the noise created by the rail systems. The noise originating from rail systems can generally be divided into three categories: noise originating from railway vehicles, vehicle–rail interaction, and train operating speed (Öztürk & Arlı, 2009). Noise from rolling stock can be classified as noise from electric and diesel train engines, the number and length of locomotives and wagons, and train auxiliary systems (Thompson, 2009). The noises caused by vehicle-railway interaction consist of many types such as rolling noise between rail and wheel, wheel roar noise, wheel squeal, irregularities in the rails, noise caused by fluctuations, sleepers, switches, viaducts and station crossings (Schneider et al., 1988). Train operating speed is also a parameter that affects railway noise levels (Yuan et al., 2026). As the operating speed increases, the rail-wheel interaction and wheel hum also increase. Ivanov et al. (2017) stated in their study that as the maximum speed of high-speed trains increased, the resulting noise value also increased. Acceleration and braking during the take-off and stops

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of the trains at the stations also create noise caused by the friction between the rail and the wheel (Thompson, 2009).

Rail system environmental noise criteria have been determined according to standards and regulations such as the “Assessment and Management of Environmental Noise” and “Railway Noise”. Regulations have been prepared in many countries to reduce the negative effects of environmental noise on physical and mental health and to establish mitigation strategies. In Türkiye, the negative effects of environmental noise on human beings and the methods to reduce these negative effects were determined with the "Regulation on Evaluation and Management of Environmental Noise" created in 2022. The report about railway noise in Europe was published by UIC. The aims of the regulation and report are to prepare noise maps, acoustic reports and environmental noise assessment reports according to environmental noise exposure levels, and to prepare action plans for reducing and preventing noise in places where environmental noise should be reduced, and to follow up the practices. Environmental noise criteria and limits in rail systems are also specified in the regulation. The noise level limits vary from country to country, but generally range from 50 to 70 dB(A) during the day. In Türkiye, the noise level emitted from rail systems to the environment cannot exceed the limit values of 65 dB(A) during daytime, 60 dB(A) in the evening and 55 dB(A) at night (Ministry of Environment, Urbanization and Climate Change, 2022; UIC, 2021).

The noise generated in the railway can be reduced by measures and regulations that can be taken at the sources that cause noise, as well as by some applications to be made on the railway side; thus, the spread and effect of noise around the railway can be reduced (Andrés et al., 2022; Öztürk & Arlı, 2009; UIC, 2021).

Some mitigation measures can be implemented directly at the railway noise source to reduce environmental noise levels. These measures include improvements in train engine design, the use of sound-absorbing materials on wheels, regular wheel and rail maintenance, rail grinding, welded rail connections, disc brake systems, electromechanical slip control during acceleration and braking, maintenance of rail irregularities, and the installation of sound-absorbing barriers along railway lines (Ivanov et al., 2017; Öztürk & Arlı, 2009; Zhang et al., 2018). Depending on operational conditions and infrastructure characteristics, these measures may reduce railway noise levels by up to approximately 10 dB(A).

In locations where source-based mitigation measures are insufficient, additional environmental noise control applications may be required to limit railway noise propagation. Common mitigation approaches include soil embankments, lowering the railway alignment relative to the surrounding terrain, earth berms, acoustic mounds, and railway noise barriers (Andrés et al., 2022; Öztürk & Arlı, 2009; UIC, 2021). Among these methods, railway noise barriers are the most commonly applied mitigation measure, particularly in station surroundings and residential areas located close to railway corridors (Ministry of Environment, Urbanization and Climate Change, 2022; UIC, 2021).

There are many studies on railway noise and noise barriers to reduce the effects of railway noise. In some of these studies, noise measurements are made and noise maps are prepared to determine the impact of railway noise on residential areas (Morihara et al., 2021; Wosniacki & Zannin, 2021; Zhang & Ma, 2021). In some studies, measurements and analyses are performed on the levels of railway noise in places with noise barriers (Lee et al., 2021). In other studies in the literature, noise measurements were conducted in areas affected by railway noise, and simulation results were used to evaluate the effectiveness of designed noise barriers in reducing environmental noise levels (Bunn & Zannin, 2016; Fiorini, 2022; Ivanov et al., 2017; Maffei et al., 2013; Morgan et al., 1998).

In addition to international studies, environmental noise assessment research conducted in Türkiye has also contributed to the understanding of transportation-related noise exposure and mitigation strategies. For example, Avşar et al. (2010) investigated environmental noise levels associated with urban road sweepers and evaluated their impacts on surrounding areas. Similarly, Avşar et al. (2019) analyzed environmental noise and vibration levels of dry-type transformers and proposed solution alternatives within an urban case study framework. These studies highlight the importance of measurement-based environmental noise assessment and mitigation planning in urban environments.

Recent research has further emphasized the importance of frequency-dependent acoustic performance and optimized barrier geometry in railway noise control. Zhang et al. (2025) investigated the aerodynamic noise reduction performance of different barrier configurations for high-speed railways and demonstrated that barrier effectiveness varies significantly across frequency bands.

Kumar and Chowdary (2024) evaluated railway boundary wall performance using CFD-based simulations and highlighted the necessity of validating predictive acoustic models with real field measurements. Their findings indicated that optimized barrier geometry and material configuration resulted in noticeable reductions in equivalent noise levels at receiver locations. However, discrepancies between simulated and measured values were observed, reinforcing the importance of post-installation validation in railway noise mitigation projects.

Furthermore, a systematic review of sustainable railway noise barrier materials showed that the acoustic insulation properties of barriers are significantly influenced by material composition, surface absorption properties, and octave-band performance (Ilonko et al., 2025; Shahidan et al., 2017). The recent review on acoustic metamaterials also proposed advanced solutions to improve low-frequency noise reduction, which remains one of the main challenges in traditional barrier applications (Wang et al., 2025).

Despite these advancements, limited studies have adopted an integrated methodology combining pre-installation field measurements, simulation-based optimization, and post-installation validation within the same case study framework (Kumar & Chowdary, 2024; Zhang et al., 2025). In line with these findings, this study not only presents simulation results obtained during the design phase but also comprehensively evaluates the real-world performance of the designed aluminum noise barrier under actual field conditions. For this purpose, a validation-based integrated methodology was implemented by comparing pre-installation measurements, simulation-based predictions, and post-installation field data. In this way, the relationship between predictive modelling and real implementation outcomes is systematically examined, aiming to address a significant gap in the existing literature.

Within the scope of this research, environmental noise levels around Arifiye Train Station were measured prior to the installation of the noise barrier, and corresponding noise maps were prepared. Subsequently, noise levels were simulated for the designed aluminum barrier configuration. Following the construction of the noise barriers, post-installation measurements were conducted and the results were systematically compared with the simulation outcomes. In addition, variations in noise levels with respect to building floor height in nearby residential areas were analyzed. The primary objective of this study is to evaluate the consistency between simulation-based predictions and field measurements, as well as to assess the influence of barrier height on overall noise reduction performance.

The remainder of this paper is organized as follows. Section 2 presents the noise measurement procedures, noise mapping methodology, and noise barrier analysis. Section 3 introduces the case study area and the characteristics of the study region. Section 4 presents the results and discussion, including comparative evaluations of measured and simulated noise data.

II. MATERIALS AND METHODS

This section provides methodological information regarding noise measurements, noise mapping procedures, and the design and evaluation of railway noise barriers.

In cases where railway noise levels cannot be reduced to acceptable limits at the source, railway authorities are required to prepare strategic noise maps in accordance with environmental noise regulations and implement mitigation measures based on an action plan. Such action plans generally include the following steps (Ministry of Environment, Urbanization and Climate Change, 2022; UIC, 2021):

- Preparation of noise maps based on field measurements conducted in areas affected by railway noise
- Design of appropriate railway noise barrier systems to reduce environmental noise levels
- Re-evaluation and comparison of noise maps after noise barrier installation

A. Noise Measurements and Noise Mapping

Sound pressure levels may vary over time or occur intermittently. In order to measure such sound levels and evaluate their effects, a noise level is determined by taking the average value of sound pressures in a certain period of time. This determined noise level is called the equivalent noise level (Leq) which is calculated by Equation 1. The unit used to express the sound level is the decibel (dB) unit, which is a logarithmic function of the acoustic pressure. For environmental noise assessment, A-weighted sound levels are used to reflect human hearing sensitivity and are expressed as dB(A) (Ministry of Environment, Urbanization and Climate Change, 2022).

$$L_{eq} = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} 10^{L_i/10} \right) \quad (1)$$

where L_{eq} is the equivalent noise level, L_i represents individual measured sound levels in dB(A), and n denotes the number of measurements.

For railway noise assessment, the long-term A-weighted equivalent sound level is calculated by Equation 2.

$$L_{Aeq} = 10 \log \left(\frac{1}{N} \sum_{i=1}^{N} 10^{L_{Aeq,T}/10} \right) \quad (2)$$

where L_{Aeq} represents the long-term A-weighted equivalent noise level and N denotes the reference time interval.

In this study, environmental noise measurements were evaluated primarily using the equivalent continuous A-weighted sound pressure level (LAeq), which is the principal descriptor recommended by international environmental noise assessment standards for regulatory compliance evaluation (International Organization for Standardization, 2016). The use of LAeq enables direct comparison with environmental noise limit values and provides a consistent framework for assessing pre- and post-installation conditions.

It is well established that railway noise exhibits frequency-dependent characteristics, with rolling noise components generally dominant in the mid-frequency range and aerodynamic noise components becoming more significant at higher operational speeds (Horoshenkov & Swift, 2001). Although octave-band measurements can provide additional spectral information, the primary objective of this research is to evaluate overall environmental noise reduction performance and to validate simulation-based predictions through field measurements. Therefore, broadband LAeq measurements were considered appropriate within the scope of the present validation-oriented methodology.

Strategic noise maps were prepared in accordance with current legislation. According to the applicable regulations, the EU Intermediate Method (Reken-Meetvoorschrift Railverkeerslawaai 1996 – RMR) was applied in processing railway traffic noise data. The resulting strategic noise map is presented in Figure 1.

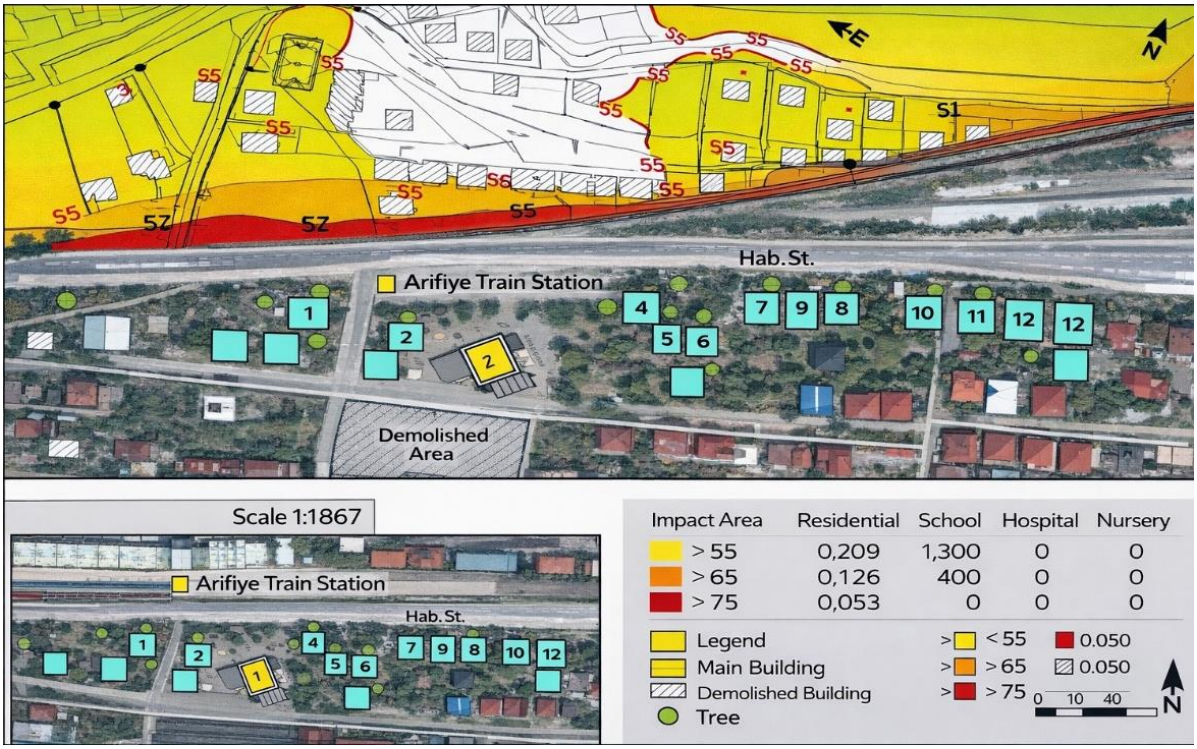


Figure 1. Strategic noise map.

B. Noise Barriers

Noise barriers are widely used to control the noise caused by the normal rolling movement of the wheels during the movement of railway and road vehicles. They are especially applied in railway stations and residential areas located close to railway lines to limit the propagation of railway noise to surrounding environments. Their application has significantly increased in Europe, the Far East (e.g., China, Japan, South Korea), and the United States (Ivanov et al., 2017; Zhang & Ma, 2021).

Noise barriers can be constructed using different materials and geometrical configurations depending on operational requirements. To improve acoustic performance, sound-absorbing materials may be incorporated into barrier structures manufactured from prefabricated concrete, aluminum, fiber-reinforced steel, cement composites, fiber-reinforced basalt, glass, and plastic-based materials (Liu et al., 2023).

Noise barriers can be installed at different heights depending on noise maps and surrounding environmental conditions. Barrier heights between 2 and 4 m are commonly used in railway applications. Depending on their configuration and material properties, noise barriers may provide average reductions of approximately 5–12 dB(A) under typical railway noise conditions (Lee et al., 2021; Öztürk & Arlı, 2009). Noise barrier design should be performed in accordance with relevant international standards.

The acoustic performance of noise barriers varies depending on frequency, material properties, surface absorption characteristics, and geometric configuration. Experimental and numerical studies have demonstrated that barrier effectiveness differs significantly across frequency bands, particularly when geometric modifications or partially enclosed configurations are introduced (Li et al., 2020).

Noise barrier design and performance assessment were conducted in accordance with the following European standards:

- EN 14388: Road traffic noise reducing devices
- EN 1793-1: Test method to determine the acoustic properties. Part 1: Product – specific characteristics of sound absorption
- EN 1793-2: Test method to determine the acoustic properties. Part 2: Product –specific characteristics of airborne sound insulation
- EN 1793-3 Test method to determine the acoustic properties. Part 3: Normalized traffic noise spectrum

III. CASE STUDY

In this section, the study area affected by railway noise is introduced, and the corresponding noise measurements and noise mapping procedures are presented. In addition, the design and optimization process of the aluminum railway noise barrier developed to reduce environmental noise levels below regulatory limits is explained in detail.

The case study was conducted around Arifiye Train Station. Arifiye is a district of Sakarya, which is one of the major cities in Türkiye. Sakarya is located in the Marmara region between Türkiye's two largest metropolitan cities, Istanbul and Ankara. Arifiye is located on the Istanbul–Ankara High-Speed Railway Line. Approximately 30 high-speed trains and 42 suburban trains pass through Arifiye Train Station daily. The station is located very close to residential areas, making nearby buildings directly exposed to railway noise.

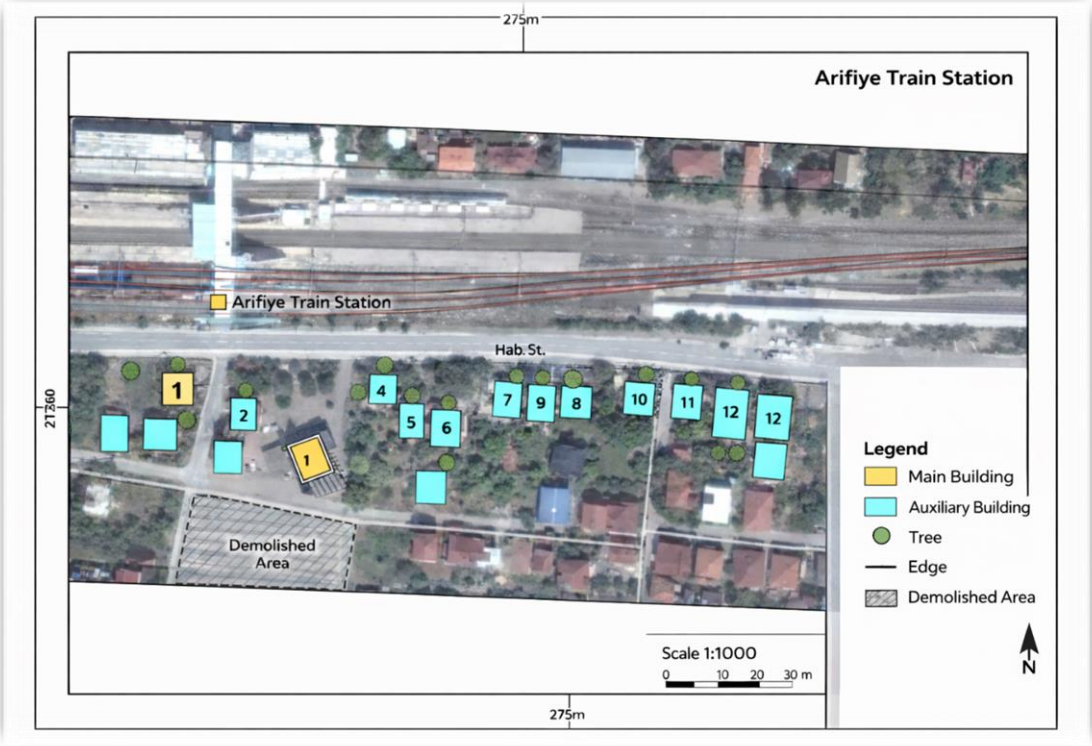


Figure 2. Arifiye Train Station and surroundings.

As can be seen in Figure 2, there are residences affected by railway noise around Arifiye Train Station.

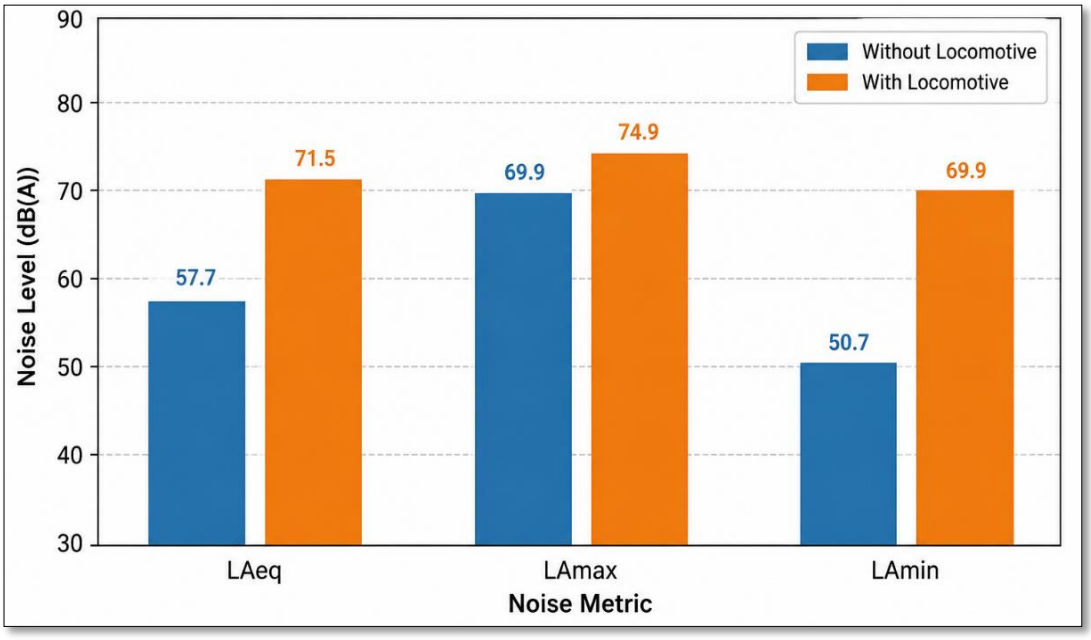


Figure 3. Comparison of measured LAeq, LAmax, and LAmin values with and without locomotive operation.

As shown in Figure 3, locomotive operation resulted in noticeable increases in LAeq, LAmax, and LAmin values measured near the residential buildings closest to the railway corridor. The most substantial increase was observed for the LAmin parameter, indicating a considerable rise in background environmental noise during locomotive operation.

Table 1. Noise levels measured at residential receiver locations before noise barrier installation.

Receiver	Floor Level	Direction	Existing Condition			
			L_{den} dB(A)	L_{daily} dB(A)	$L_{evening}$ dB(A)	L_{night} dB(A)
1	Ground floor	North	79.7	73.0	71.8	73.5
1	First floor	North	79.7	73.0	71.7	73.5
2	Ground floor	North	78.3	71.6	70.4	72.1
2	First floor	North	78.3	71.6	70.4	72.1
3	Ground floor	Southwest	75.9	69.2	68.0	69.7
3	First floor	Southwest	75.9	69.2	68.0	69.7
4	Ground floor	North	80.2	73.5	72.3	74.0
4	First floor	North	80.1	73.5	72.2	74.0
5	Ground floor	North	77.3	70.6	69.4	71.1
5	First floor	North	77.3	70.6	69.4	71.1
6	Ground floor	North	77.5	70.8	69.5	71.3
6	First floor	North	77.4	70.8	69.5	71.3
7	Ground floor	North	79.0	72.3	71.0	72.8
7	First floor	North	78.9	72.3	71.0	72.8
8	Ground floor	North	78.7	72.0	70.8	72.5
8	First floor	North	78.7	72.0	70.7	72.5
9	Ground floor	North	78.3	71.6	70.4	72.1
9	First floor	North	78.3	71.6	70.3	72.1
10	Ground floor	North	78.3	71.7	70.4	72.2
10	First floor	North	78.3	71.7	70.4	72.2
11	Ground floor	North	78.4	71.7	70.4	72.2
11	First floor	North	78.3	71.7	70.4	72.2
12	Ground floor	North	77.6	70.9	69.7	71.5
12	First floor	North	77.6	70.9	69.7	71.4

The measured noise levels at all receiver locations exceeded the environmental railway noise limits specified in the applicable regulations, particularly during daytime and nighttime periods.

$$L_{den} = 10 \log \left[\frac{1}{24} \left(12 \times 10^{L_{daily}/10} + 4 \times 10^{(L_{evening}+5)/10} + 8 \times 10^{(L_{night}+10)/10} \right) \right] \quad (3)$$

Daytime: 07:00–19:00 (12 h)

Evening: 19:00–23:00 (4 h)

Night: 23:00–07:00 (8 h)

where L_{den} represents the day–evening–night noise level expressed in dB(A), L_{daily} is the A-weighted long-term average sound level during the daytime period, $L_{evening}$ is the A-weighted long-term average sound level during the evening period, and L_{night} is the A-weighted long-term average sound level during the nighttime period.

Noise measurements were conducted at the ground and first floors, which are the building levels most directly exposed to railway noise. Table 1 shows that the noise values measured at the receivers in the settlements near the railway are above the limit values specified in Table 2.

Table 2. Environmental railway noise limit values according to national regulations.

L_{daily} dB(A)	$L_{evening}$ dB(A)	L_{night} dB(A)	L_{den} dB(A)
65	60	55	65

In the process of creating the maps, the site plan of the area where the buildings around the Arifiye railway station are located was obtained from Google Earth and transferred to the SoundPLAN 7.4 (64 bit) program and its topographic features were modeled in three dimensions.

SoundPLAN noise modeling program, which is widely used all over the world, was used for mapping. With this program, it is possible to create noise maps to determine the noise levels at the desired points on the building surfaces and to calculate the source sound levels depending on different standards. With the SoundPLAN Program, the field map of the land was created with the ITRF 96 coordinate system. In order for the structures in the region to be defined in the program, the formal and dimensional features such as building height, number of floors, storey heights and numerical information were entered into the program.

The prepared model enabled the evaluation of pre- and post-installation railway noise conditions under comparable simulation settings.

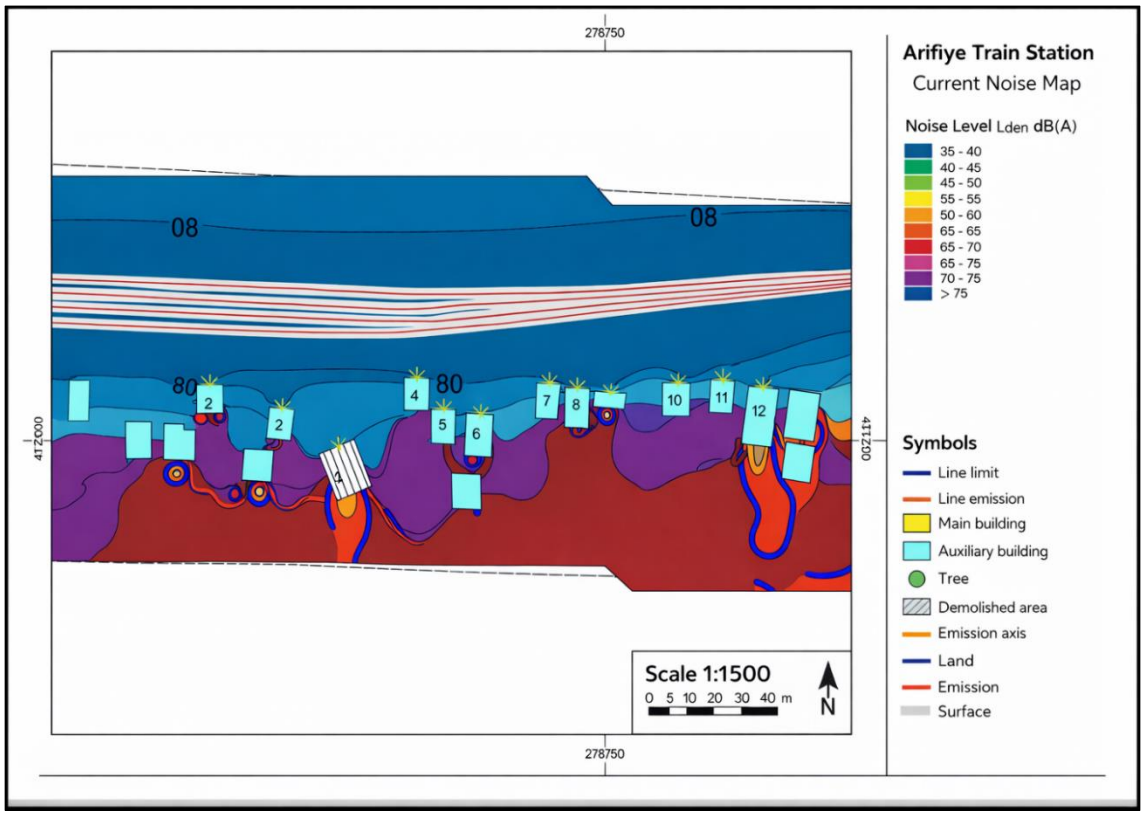


Figure 4. Existing environmental L_{den} noise map of Arifiye Train Station and surrounding area.

As a result of the noise measurements and simulation analyses, daily average and nighttime noise maps were generated for the area surrounding Arifiye Train Station, as presented in Figures 4 and 5.

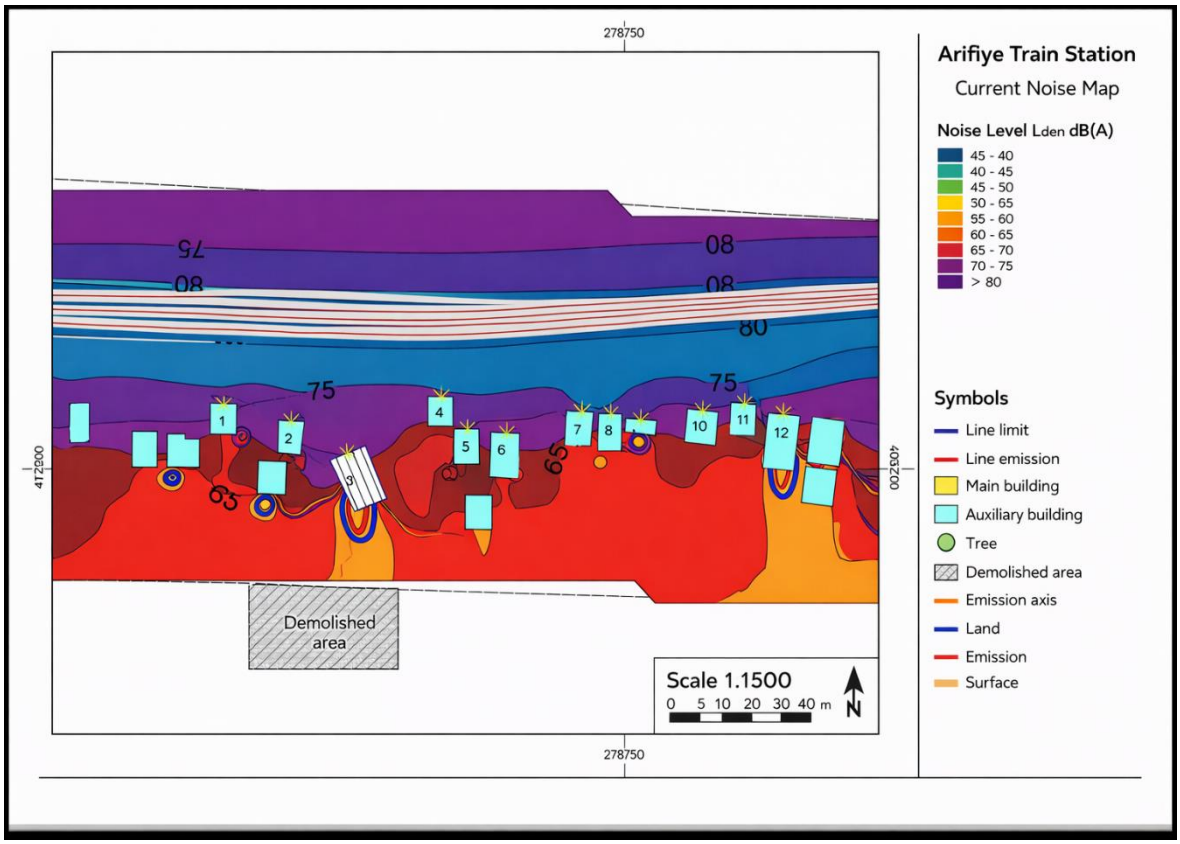


Figure 5. Existing environmental L_{night} noise map of Arifiye Train Station and surrounding area.

A noise barrier was planned between the railway line and the adjacent residential buildings in order to mitigate the adverse effects of railway noise exposure in the study area. The barrier, positioned along the railway boundary, was designed with an optimized height and a single-sided sound-absorbing surface facing the railway line to enhance acoustic performance and reduce reflected sound energy.

The acoustic effectiveness of noise barriers is influenced by geometric configuration, material composition, and frequency-dependent attenuation characteristics. Previous experimental and numerical studies have demonstrated that barrier performance varies across frequency bands, particularly depending on structural configuration and enclosure conditions (Li et al., 2020). Therefore, the selected aluminum barrier system was evaluated considering its expected acoustic behavior under typical railway noise spectra.

After modeling the noise barrier, virtual receiver points were defined at different floor levels of the residential buildings in order to assess the vertical distribution of railway noise levels. Noise levels at these receiver locations were calculated separately for daytime, evening, and nighttime periods using the SoundPLAN simulation software.

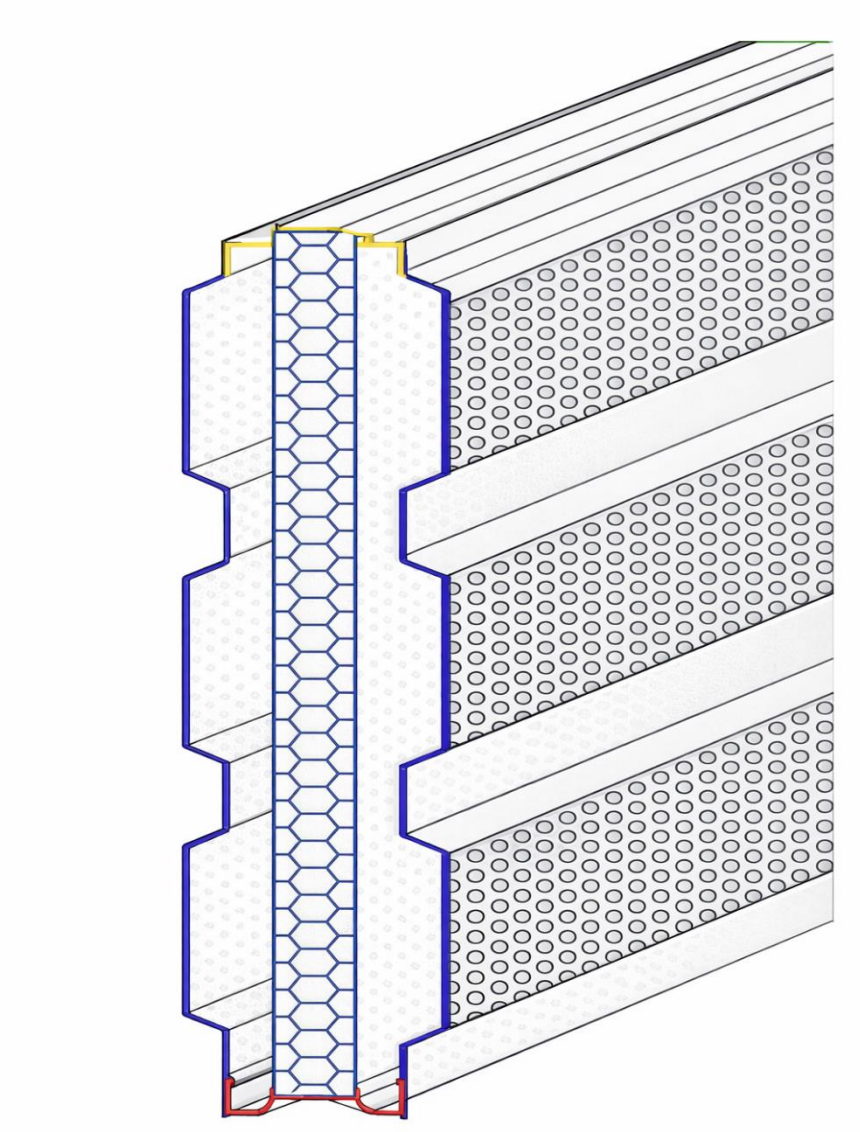


Figure 6. Cross-sectional view of the aluminum railway noise barrier.

Looking at the noise measurement values presented in Table 1 and Figures. 4 and 5, the noise barrier was required to provide a minimum sound attenuation of approximately 11 dB(A) in order to reduce environmental noise levels below the regulatory limits. The cross-sectional design of the aluminum railway noise barrier satisfying these requirements is presented in Figure. 6.

In this study, environmental noise evaluation was primarily based on the equivalent continuous A-weighted sound pressure level (LAeq), which is recommended for regulatory compliance assessment (International Organization for Standardization, 2016.). Although octave-band measurements were not available, railway noise is known to exhibit frequency-dependent characteristics, with rolling noise components typically dominant in the mid-frequency range (Horoshenkov & Swift, 2001). Therefore, the interpretation of overall LAeq reductions was made considering the expected spectral attenuation characteristics reported in the literature.

The height and length of the noise barrier were optimized to ensure that noise levels at affected residential buildings remained below the applicable environmental noise limit values. As a result of the optimization process, the barrier system illustrated in the site plan shown in Figure. 7 was designed with a height of 4 m and a total length of 250 m.

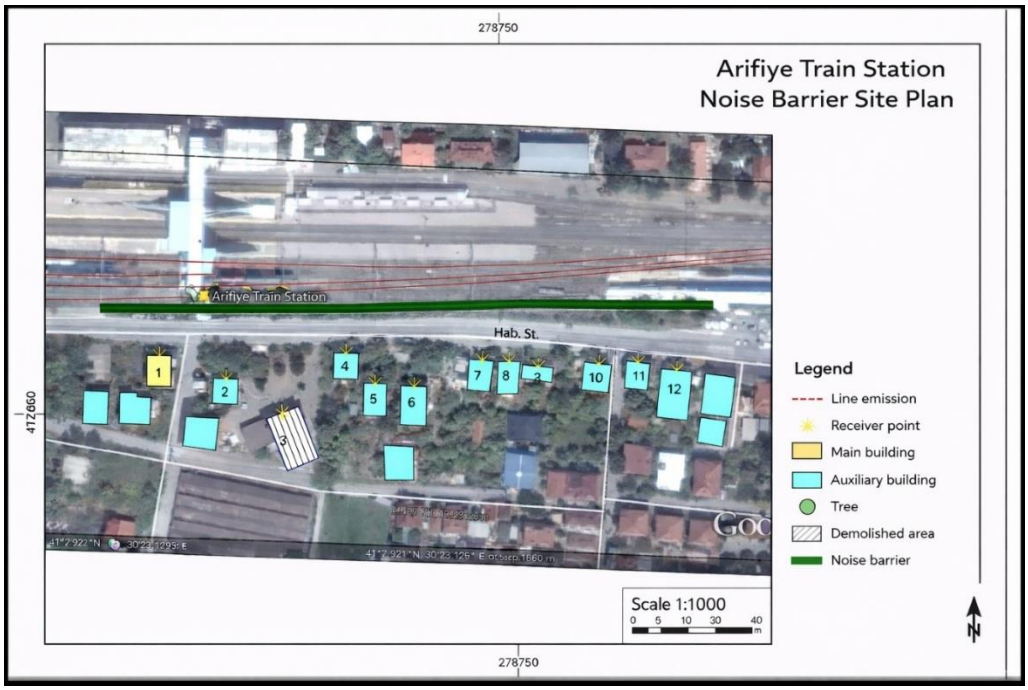


Figure 7. Noise barrier site plan at Arifiye Train Station.

IV. RESULTS AND DISCUSSION

In this section, the simulation results of railway noise and the post-installation measurement results obtained after the construction of the aluminum railway noise barrier are presented.

Firstly, simulation-based environmental noise levels obtained after the installation of the railway noise barrier are evaluated for residential buildings located near the railway corridor. The differences between pre-installation and post-installation noise conditions are presented using strategic noise maps.

Daily average and nighttime simulation results for the residential area after noise barrier installation are presented in Figures. 8 and 9. As shown in Figure. 8, the daily average noise levels measured at residential buildings closest to the railway line (Receivers 1–12) were reduced to approximately 55–60 dB(A), indicated by the orange-colored regions on the noise map.

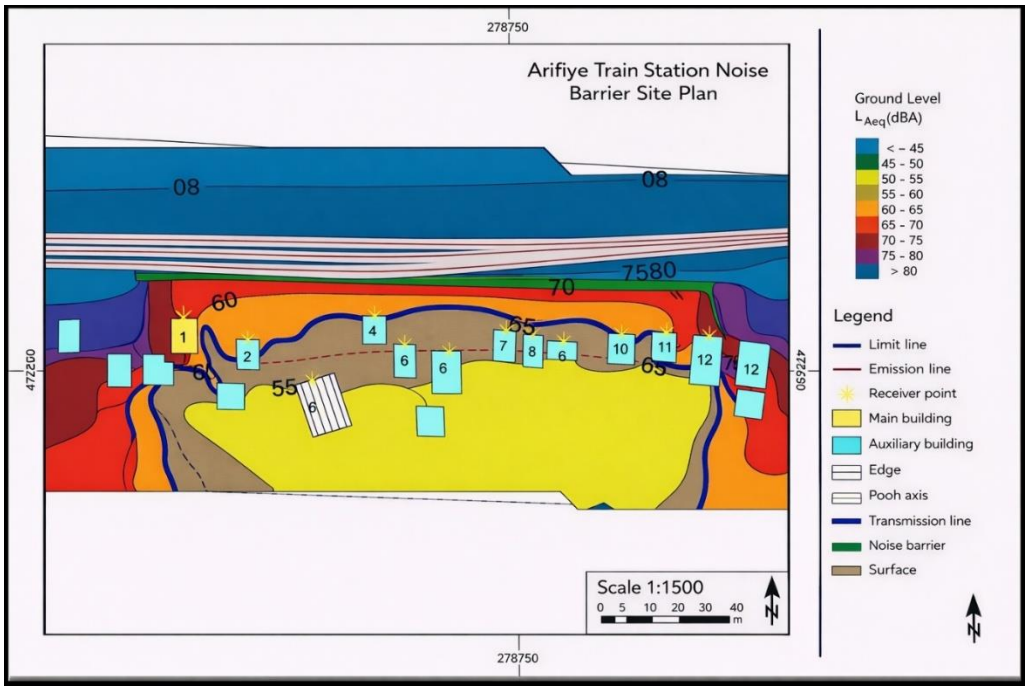


Figure 8. Simulated L_{den} noise map after aluminum railway noise barrier installation.

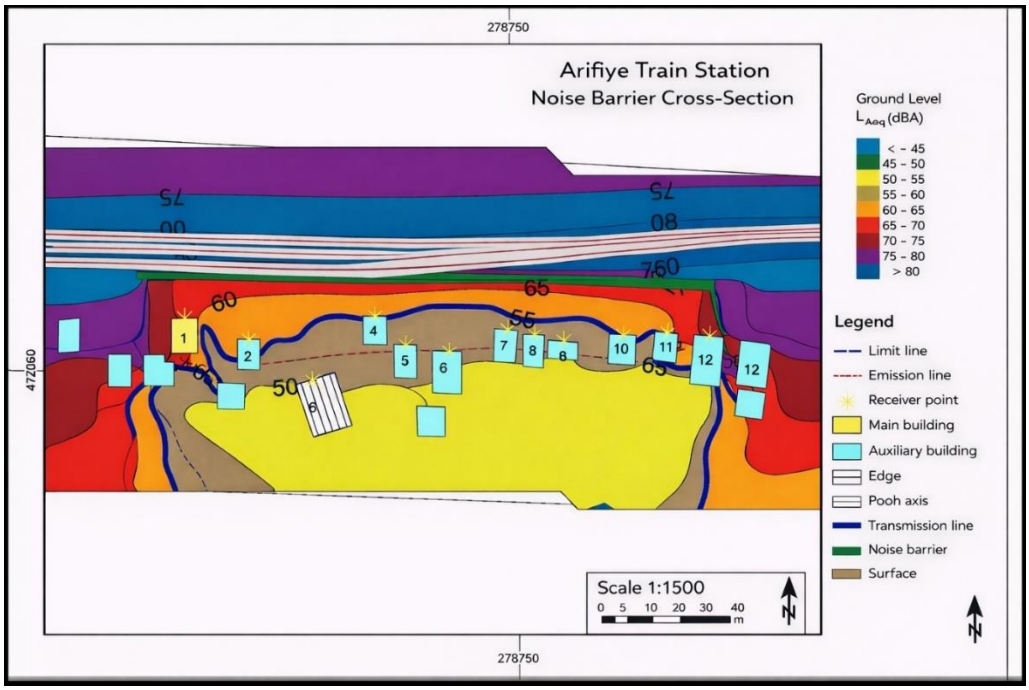


Figure 9. Simulated L_{night} noise map after aluminum railway noise barrier installation.

As shown in Figure 9, the simulated nighttime noise levels in the residential area were generally within the range of 50–55 dB(A) after noise barrier installation. According to environmental noise regulations, the highest railway noise exposure levels are generally observed at elevations up to 4.2 m above ground level (Ministry of Environment, Urbanization and Climate Change, 2022). Therefore, noise evaluations and simulation measurements were conducted for the ground and first floors of the residential buildings.

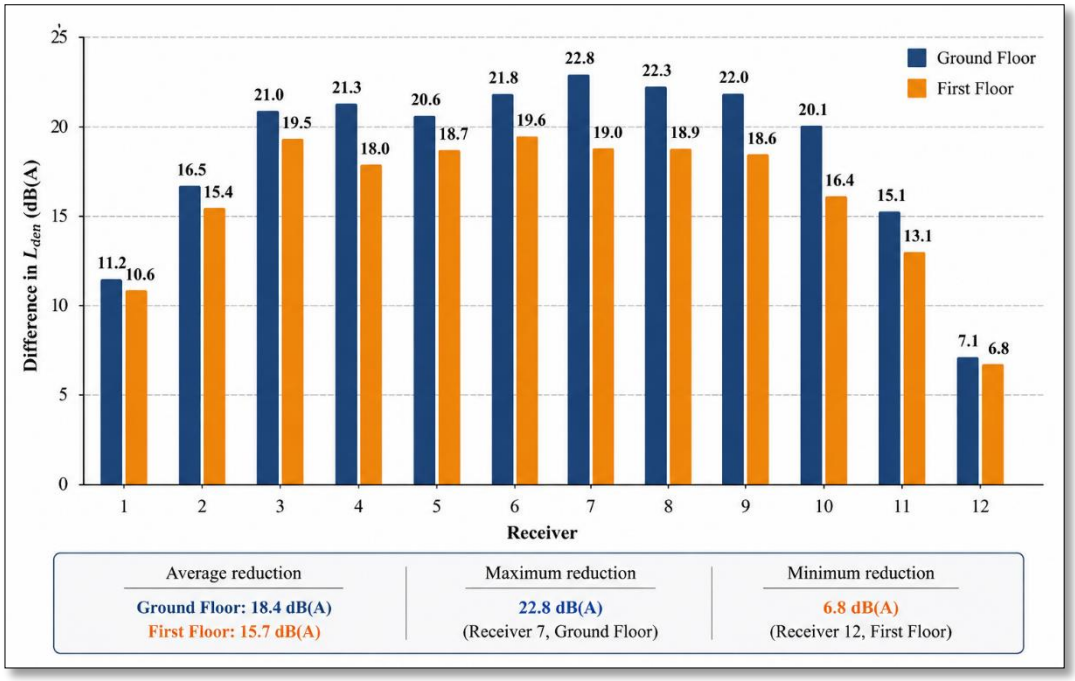


Figure 10. Comparison of simulated L_{den} reductions at ground and first floors after aluminum railway noise barrier installation.

Figure 10 presents the simulated reductions in L_{den} noise levels for the ground and first floors of the 12 residential receiver locations following aluminum railway noise barrier installation.

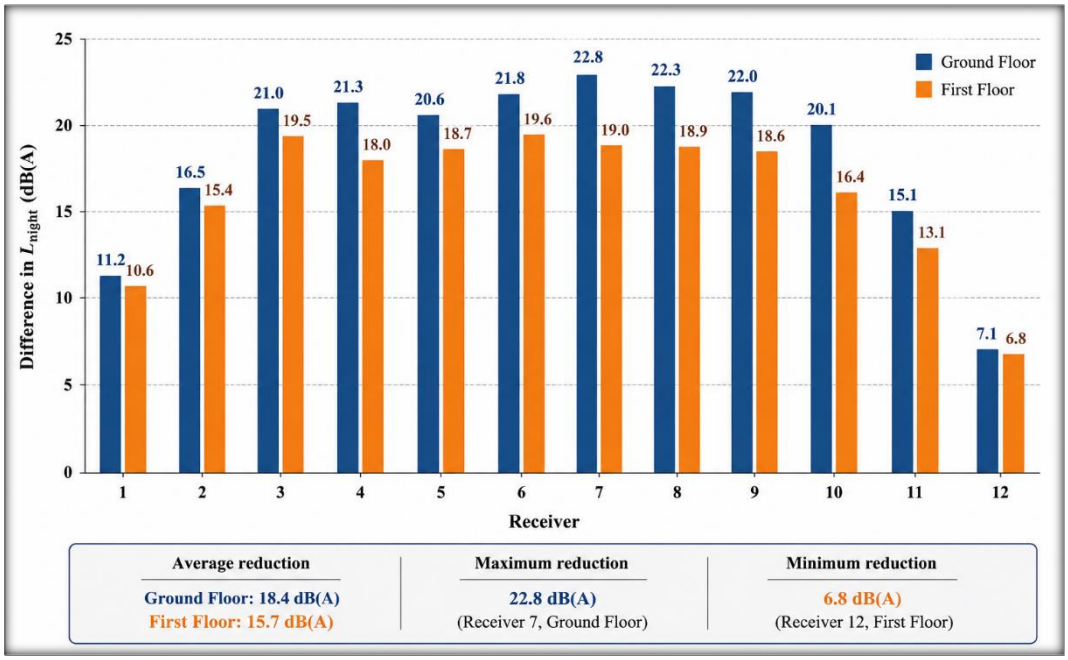


Figure 11. Comparison of simulated L_{night} reductions at ground and first floors after aluminum railway noise barrier installation

Figure 11 illustrates the simulated reductions in L_{night} noise levels at the ground and first floors of the 12 residential receiver locations after aluminum railway noise barrier installation.



Figure 12. Installation of the aluminum railway noise barrier at Arifiye Train Station.

Following the installation of the aluminum railway noise barrier illustrated in Figure 12, post-installation field measurements were conducted to evaluate the effectiveness of the mitigation system. The measured environmental noise levels were recorded as 58.3 dB(A), for L_{daily} 63 dB(A), for $L_{evening}$ 58 dB(A), for L_{night}, and 51 dB(A) for L_{den}.

The daily average environmental noise level of 71.5 dB(A) was predicted to decrease to 53.9 dB(A) according to the simulation results after noise barrier installation. However, post-installation field measurements indicated that the noise level decreased to approximately 58 dB(A), which is below the applicable environmental noise limit value. While the simulation predicted a noise reduction of approximately 17.6 dB(A), the measured reduction under real operating conditions was approximately 13.5 dB(A). Although the simulated reduction level was not fully achieved, the installed

aluminum railway noise barrier successfully reduced environmental noise levels below the regulatory threshold.

When the simulation results and post-installation field measurements were compared, an overall difference of approximately 4.1 dB(A) was observed. This discrepancy may be associated with operational variability, differences in train types and characteristics, environmental conditions, and practical implementation-related factors not fully represented in the simulation model.

This comparison highlights the importance of validating simulation-based predictions through post-installation field measurements under real environmental and operational conditions. Differences between simulation and field data may arise from operational variability, differences in train characteristics, environmental conditions, and simplifications adopted during the simulation process.

This study investigated railway noise and its effects on residential areas located near railway corridors. Environmental noise measurements were conducted at all residential receiver locations affected by railway noise within the selected study area. An aluminum railway noise barrier was selected and optimized to reduce environmental noise levels below the applicable regulatory limits.

Unlike many previous studies, daytime, evening, nighttime, and overall L_{den} noise levels were evaluated simultaneously for all affected residential receiver locations (Bunn & Zannin, 2016; Ivanov et al., 2017; Němec et al., 2020). In addition, both simulation-based predictions and post-installation field measurements were comparatively assessed within the same case study framework. Thus, the study contributes to the literature by providing an integrated assessment methodology combining pre-installation measurements, simulation-based optimization, and post-installation validation for railway noise mitigation applications.

The findings of this study demonstrate that aluminum railway noise barriers can effectively mitigate environmental railway noise in densely populated residential areas when appropriately designed according to site-specific geometric and operational conditions. Although octave-band measurements were not available within the scope of this study, the observed reductions in overall LAeq values indicate that the designed barrier system provided effective environmental noise mitigation under real operating conditions.

Future studies may incorporate frequency-dependent spectral analyses and long-term monitoring approaches to further evaluate railway noise barrier performance under varying operational and environmental conditions. As railway transportation continues to expand worldwide, validation-based methodologies integrating simulation and field measurements are expected to play an increasingly important role in the development of sustainable railway noise mitigation strategies.

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REFERENCES

Andrés, V. T., Martínez-Casas, J., Denia, F. D., & Thompson, D. J. (2022). Influence study of rail geometry and track properties on railway rolling noise. *Journal of Sound and Vibration, 525*, Article 116701. https://doi.org/10.1016/j.jsv.2021.116701

Avşar, E., Erol, H., Toröz, İ., & Piro, E. (2019). Evaluation of environmental noise and vibration levels of dry-type transformers and determination of solution alternatives: Istanbul case study. *Bitlis Eren University Journal of Science and Technology, 8*(3), 958–967. https://doi.org/10.17798/bitlisfen.519250

Avşar, E., Hanedar, A., Toröz, İ., Alp, K., & Kaynak, B. (2010). Investigation of PM_{10} concentrations and noise levels of the road sweepers operating in Istanbul-Türkiye: A case study. *Fresenius Environmental Bulletin, 19*(9), 2033–2039.

Bunn, F., & Zannin, P. H. T. (2016). Assessment of railway noise in an urban setting. *Applied Acoustics, 104*, 16–23.

https://doi.org/10.1016/j.apacoust.2015.10.025
European Environment Agency (EEA). (2025). *Environmental noise in Europe 2025*. Publications Office of the European Union. https://www.eea.europa.eu/en/analysis/publications/environmental-noise-in-europe-2025
Fiorini, C. V. (2022). Railway noise in urban areas: Assessment and prediction on infrastructure improvement combined with settlement development and regeneration in central Italy. *Applied Acoustics, 185*, Article 108413. https://doi.org/10.1016/j.apacoust.2021.108413
Gupta, S., & Ghatak, C. (2011). Environmental noise assessment and its effect on human health in an urban area. *International Journal of Environmental Sciences, 1*(7), 1954–1964.
Horoshenkov, K. V., & Swift, M. J. (2001). The effect of consolidation on the acoustic properties of loose rubber granulates. *Applied Acoustics, 62*(6), 665–690. https://doi.org/10.1016/S0003-682X(00)00069-4
Ilonko, W. A., Handayani, D., & Soeryodarundio, K. (2025). A systematic review of sustainable materials for railway activity noise barriers in Indonesia. *Engineering Proceedings, 84*(1), Article 23. https://doi.org/10.3390/engproc2025084023
International Organization for Standardization. (2016). *Acoustics—Description, measurement and assessment of environmental noise—Part 1: Basic quantities and assessment procedures (ISO Standard No. 1996-1:2016)*. https://www.iso.org/standard/59765.html
International Union of Railways (UIC). (2021). *Railway noise in Europe: State of the art report.* International Union of Railways. https://uic.org/IMG/pdf/railway_noise_in_europe_state_of_the_art_report.pdf
International Union of Railways (UIC). (2024). *UIC activity report 2024*. International Union of Railways. https://uic.org/IMG/pdf/uic_activity_report_2024.pdf
Ivanov, N. I., Boiko, I. S., & Shashurin, A. E. (2017). The problem of high-speed railway noise prediction and reduction. *Procedia Engineering, 189*, 539–546. https://doi.org/10.1016/j.proeng.2017.05.086
Kumar, B. S., & Chowdary, V. (2024). Acoustic performance evaluation of railway boundary walls using a computational fluid dynamics-based simulation approach. *Environmental Science and Pollution Research, 31*, 24344–24359. https://doi.org/10.1007/s11356-024-32722-2
Lee, H. P., Lim, K. M., & Kumar, S. (2021). Noise assessment of elevated rapid transit railway lines and acoustic performance comparison of different noise barriers for mitigation of elevated railway track noise. *Applied Acoustics, 183,* Article 108340. https://doi.org/10.1016/j.apacoust.2021.108340
Li, Q., Duhamel, D., Luo, Y., & Yin, H. (2020). Analysing the acoustic performance of a nearly enclosed noise barrier using scale model experiments and a 2.5-D BEM approach. *Applied Acoustics, 158,* Article 107079. https://doi.org/10.1016/j.apacoust.2019.107079
Liu, D., Wang, C., Gonzalez-Libreros, J., Tu, Y., Elfgren, L., & Sas, G. (2023). A review on aerodynamic load and dynamic behavior of railway noise barriers when high-speed trains pass. *Journal of Wind Engineering and Industrial Aerodynamics, 239*, Article 105458. https://doi.org/10.1016/j.jweia.2023.105458
Ministry of Environment, Urbanization and Climate Change. (2022). *Environmental Noise Control Regulation. Official Gazette* (No. 32029).
Maffei, L., Masullo, M., Aletta, F., & Gabriele, M. D. (2013). The influence of visual characteristics of barriers on railway noise perception. *Science of the Total Environment, 445-446*, 41–47. https://doi.org/10.1016/j.scitotenv.2012.12.025
Morgan, P. A., Hothersall, D. C., & Chandler-Wilde, S. N. (1998). Influence of shape and absorbing surface—A numerical study of railway noise barriers. *Journal of Sound and Vibration, 217*(3), 405–417. https://doi.org/10.1006/jsvi.1998.1773
Morihara, T., Yokoshima, S., & Matsumoto, Y. (2021). Effects of noise and vibration due to the Hokuriku Shinkansen railway on the living environment: A socio-acoustic survey one year after the opening. *International Journal of Environmental Research and Public Health, 18*(15), Article 7794. https://doi.org/10.3390/ijerph18157794
Moritoh, Y., Zenda, Y., & Nagakura, K. (1996). Noise control of high-speed Shinkansen. *Journal of Sound and Vibration, 193*(1), 319–334. https://doi.org/10.1006/jsvi.1996.0273
Muzet, A. (2007). Environmental noise, sleep and health. *Sleep Medicine Reviews, 11*(2), 135–142. https://doi.org/10.1016/j.smrv.2006.09.001
Némec, M., Danihelová, A., Gergel, T., Gejdoš, M., Ondrejka, V., & Danihelová, Z. (2020). Measurement and prediction of railway noise: Case study from Slovakia. *International Journal of Environmental Research and Public Health, 17*(10), Article 3616. https://doi.org/10.3390/ijerph17103616
Öztürk, Z., & Arlı, V. (2009). Railway engineering. İstanbul Ulaşım A.Ş.
Schneider, E., Popp, K., & Irretier, H. (1988). Noise generation in railway wheels due to rail-wheel contact forces. *Journal of Sound and Vibration, 120*(2), 227–244. https://doi.org/10.1016/0022-460X(88)90431-2
Shahidan, S., Hannan, N. I. R. R., Maaro, M. Z. M., Leman, A. S., & Senin, M. S. (2017). A comprehensive review on the effectiveness of existing noise barriers commonly used in the railway industry. *MATEC Web of Conferences, 87*, Article 01007. https://doi.org/10.1051/matecconf/20178701007
Thompson, D. (2009). *Railway noise and vibration: Mechanisms, modelling and means of control.* Elsevier.
Wang, C., Wang, G., Chen, Z., Lim, C. W., & Chen, W. (2025). Vibration control and noise attenuation strategies via acoustic metamaterial in railway transportation: A state-of-the-art review. *Urban Lifeline, 3*, Article 14.

https://doi.org/10.1007/s44285-025-00043-6
World Health Organization. (2018). *Environmental noise guidelines for the European Region.* https://www.who.int/europe/publications/i/item/9789289053563
Wosniacki, G. G., & Zannin, P. H. T. (2021). Framework to manage railway noise exposure in Brazil based on field measurements and strategic noise mapping at the local level. *Science of the Total Environment, 757*, Article 143721. https://doi.org/10.1016/j.scitotenv.2020.143721
Yang, X., Li, X., Ning, B., & Tang, T. (2016). A survey on energy-efficient train operation for urban rail transit. *IEEE Transactions on Intelligent Transportation Systems, 17*(1), 2–13. https://doi.org/10.1109/TITS.2015.2447507
Yuan, Y., Li, X., Cheng, Y., He, H., Yang, Z., Jiang, X., & Wu, D. (2026). Acoustic characteristic optimal design for railway steel–concrete composite bridge based on the RBFNN-NSGA-II algorithm. *Railway Engineering Science, 34*, 333–348. https://doi.org/10.1007/s40534-025-00385-5
Zhang, J., Xiao, X., Sheng, X., Li, Z., & Jin, X. (2018). A systematic approach to identify sources of abnormal interior noise for a high-speed train. *Shock and Vibration, 2018*, Article 5085847. https://doi.org/10.1155/2018/5085847
Zhang, L., & Ma, H. (2021). Investigation of Chinese residents' community response to high-speed railway noise. *Applied Acoustics, 172,* Article 107615. https://doi.org/10.1016/j.apacoust.2020.107615
Zhang, R., Li, H., Yang, J., Chen, X., & Yang, S. (2025). Study on the noise reduction effect of sound barriers on the aerodynamic noise of high-speed trains. *Frontiers in Acoustics, 3*, Article 1616806. https://doi.org/10.3389/facou.2025.1616806