forum acusticum 2026
8-12 September · Graz, Austria

Evaluation of a Noise Barrier Project: Achieved Noise Reductions and Residents' Perceived Benefit

Jakob Fryd[1], Victoria Hjørtoft[2]

[1]*Danish Road Directorate, Carsten Niebuhrs Gade 43, 1577 Copenhagen V, Denmark*
[2]*Epinion, Ryesgade 3F, 2200 Copenhagen N, Denmark*

Abstract

This paper presents an evaluation of a major noise barrier project along the E45 motorway in Aalborg, Denmark, comprising 7.725 km of new barriers with heights of 6–9 m. The evaluation combines façade noise calculations, resident questionnaire surveys and qualitative interviews. The calculations showed a substantial acoustic improvement: dwellings exposed above the Danish guideline value of 58 dB (Lden) were reduced from 1,918 to 591, with an average reduction of approximately 5 dB among dwellings above 58 dB before the project. The share of residents highly annoyed by road traffic noise at home decreased from 60% to 42%, consistent with the Danish motorway dose-response relationship, where a 5 dB reduction corresponds to approximately 18% fewer highly annoyed residents. However, many residents experienced less improvement than expected, and the relationship between the calculated noise reduction at each dwelling and the respondent's perceived noise reduction was very weak. The interviews show that assessments were also shaped by expectations, information, visual impact, local terrain, vegetation removal and the broader sound environment. The study demonstrates that noise barriers can substantially reduce noise exposure and annoyance at population level, but that perceived benefit varies considerably and cannot be assessed and described from decibel reductions alone.

Keywords: *Road traffic noise, noise barriers, noise annoyance, soundscape, resident perception.*

1. Introduction

Road traffic noise represents one of the most significant environmental challenges for residential areas located along major motorways. In Denmark, the guideline value for road traffic noise at dwellings is 58 dB (Lden). However, along motorways this level is generally difficult to achieve through conventional noise barriers alone. While barriers can provide clearly audible reductions, particularly for dwellings close to the road, they rarely eliminate the noise problem entirely.

The Danish Road Directorate implemented a major noise barrier project along the E45 motorway through Aalborg City to reduce road traffic noise in existing residential areas (see Figure 1.).

Figure 1. Overview map showing the location of the new noise barriers installed along the E45 motorway in Aalborg, Denmark.

***Corresponding author**: jaf@vd.dk.*

The project comprised 7.725 km of new barriers with heights between 6 and 9 m and represented an investment of approximately EUR 30 million. The project was financed through the national noise fund established as part of a political agreement from 2021 on Infrastructure Plan 2035, which allocated EUR 400 million for the period 2022–2035 to reduce traffic noise in highly noise-exposed residential areas along the state road network.

Given the practical limitations of reducing noise levels below 58 dB (L_{den}) at all dwellings along major motorways, the intervention in Aalborg was primarily targeted at the most heavily exposed dwellings, particularly those above 63 dB (L_{den}).

The project also aimed to ensure that the achieved noise reduction was proportionate to the investment, with cost-effectiveness assessed in terms of noise reduction per euro invested. The height and length of a noise barrier are key determinants of its noise-reducing effect: higher and more continuous barriers generally provide larger reductions, but also affect the costs of the project considerably. It is therefore important to balance the investment against the acoustic benefit that can realistically be achieved. In the Aalborg project, the total investment was approximately EUR 30 million, and the average calculated reduction for dwellings exposed above 58 dB (L_{den}) before the project was about 5 dB. This corresponds to an indicative cost of approximately EUR 15,600 per dwelling.

The project was evaluated by combining calculated façade noise levels before and after construction with resident questionnaire surveys and qualitative interviews. The aim was to assess both the acoustic effects and how the project was perceived by residents living near the motorway [1]. All noise levels in this paper are described by the noise indicator L_{den}.

2. Evaluation Method

The evaluation was based on three complementary sources: noise calculations, resident questionnaire surveys and qualitative interviews.

The noise calculations covered the section of the E45 motorway in Aalborg where the new noise barriers were installed, a stretch of approximately 5.5 km with traffic volumes of approximately 40,000–60,000 vehicles per day.

Noise levels were calculated by Sweco Denmark using the Nord2000-model. Nord2000 is a one-third octave band method developed for the prediction of yearly average environmental noise levels, i.e., taking the influence of variation in source emission and weather conditions into account. Nord2000 is considered to be the most accurate method available for predicting road traffic noise [2]. Calculations covered an area extending approximately 1,000 m from the motorway centreline. For each dwelling, the highest calculated façade level was used. Two scenarios were analysed: the reference situation before the new barriers and the project situation after inclusion of the new barriers.

Resident surveys were conducted by Epinion in 2023 before construction and in 2025 after completion. Web-based questionnaires were sent to 1,346 addresses in the noise-exposed areas along the motorway, including all residential addresses within 225 m of the motorway centreline, corresponding to up to approximately 200 m from the noise barriers. Telephone follow-up was used for residents who had not responded after approximately 1.5 weeks. Questions on noise annoyance were formulated and evaluated in accordance with ISO/TS 15666 [3], which specifies methods for assessing noise annoyance by means of social and socio-acoustic surveys. The questionnaires also covered behaviour, acceptance of noise, expectations, perceived reduction, information and attitudes towards the barriers. In total, 523 responses were obtained in 2023 and 479 in 2025, corresponding to response rates of 39% and 36%, respectively [4].

In addition, 24 qualitative interviews were conducted with three groups of residents selected to capture contrasting experiences of the project: disappointed residents with high calculated noise reductions, disappointed residents who felt insufficiently informed, and residents with a positive attitude towards the barriers. The design was chosen to explore why similar acoustic changes may be interpreted differently, and how expectations, information and local context influence residents' assessment of the barriers [5].

3. Calculated Noise Reductions

Table 1 shows the distribution of dwellings by calculated façade noise level before and after construction of the new barriers. Before the project, 1,918 dwellings were exposed to levels above 58 dB (L_{den}), including 490 dwellings above 63 dB (L_{den}). After implementation, the number of dwellings above 58 dB was reduced to 591, while the number above 63 dB was reduced to 34. The table illustrates a clear shift from the higher noise intervals to lower exposure levels, indicating that the barriers substantially reduced the number of highly exposed dwellings.

Table 1. Number of dwellings in 5-dB noise intervals before and after installation of the new noise barriers.

	Number of dwelling exposed (dB, Lden)				
Scenario	**48-53**	**53-58**	**58-63**	**63-68**	**> 68**
Before	0	0	1,428	362	128
After	62	1,265	557	34	0

Table 2 summarises the calculated noise reductions at dwellings, grouped according to their pre-project noise exposure intervals before the new noise barriers were constructed. For all dwellings above 58 dB before the project, the average reduction was 4.9 dB, with reductions increasing markedly with initial exposure: from 4.0 dB in the 58–63 dB interval to 6.5 dB in the 63–68 dB interval and 9.5 dB for dwellings above 68 dB. This pattern reflects the design objective of targeting the most noise-exposed dwellings along the motorway. At the same time, the variation within each interval shows that the effect differed between dwellings, as expected given local conditions such as

distance to the motorway, dwelling height, terrain and the relative position of the dwelling and the barrier.

Table 2. Noise reduction (L_{den}) statistics by pre-project noise interval at dwellings.

	58-63 dB	**63-68 dB**	**> 68 dB**	**> 58 dB**
Dwellings	1,428	362	128	1.918
Max. reduction	-11.2 dB	-11.7 dB	-15.5 dB	-15.5 dB
Avg. reduction	-4.0 dB	-6.5 dB	-9.5 dB	-4.9 dB
Variation	4.6 dB	6.9 dB	4.5 dB	7.5 dB
SD	2.1 dB	2.6 dB	2.1 dB	2.7 B

Overall, the calculations show that the project produced a substantial acoustic improvement, particularly for the most exposed dwellings. At the same time, the results also show that many dwellings remain exposed above the Danish guideline value of 58 dB (L_{den}), underlining that high noise barriers along motorways can reduce, but far eliminate, road traffic noise in adjacent residential areas.

4. Results from the Questionnaire Survey

The questionnaire survey shows that the residents' perceived noise situation improved after the construction of the new noise barriers, but also that the effect experienced was considerably smaller than many residents had expected.

Figure 2 shows the change in residents' reported annoyance from road traffic noise before and after construction of the noise barriers. The share of respondents who were highly annoyed by road traffic noise at home decreased from 60% to 42%. Indoors, the share of highly annoyed residents decreased from 24% to 15%, while the share reporting no or only slight indoor annoyance increased from 34% to 54%. The figure therefore indicates a clear improvement in the perceived noise situation, although a substantial proportion of residents remained annoyed after implementation.

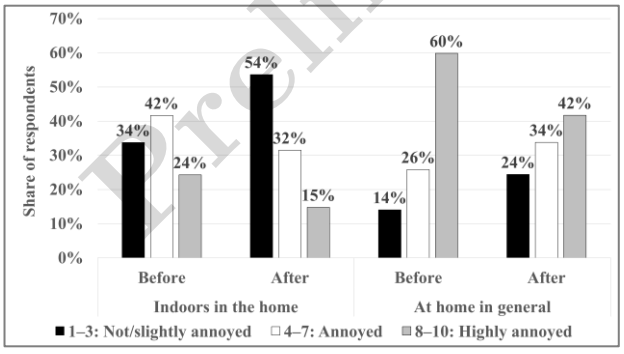

Figure 2. Distribution of respondents by degree of annoyance from motorway noise before and after installation of the noise barriers, shown separately for indoor conditions and for the home environment in general.

The survey also indicates that the barriers have reduced the extent to which residents adapt their everyday behaviour because of motorway noise. Table 3 shows a selection of the results.

Table 3. Examples of behavioural adaptations indoors and outdoors at home in response to motorway noise. In the 2023 before-survey, residents were asked to consider the previous year; in the 2025 after-survey, they were asked to consider the previous three months, corresponding approximately to the period since installation of the noise barriers.

	Before	**After**
Open the windows less than I would without road noise	56%	43%
Do not sleep with open windows because of road noise	49%	38%
Have shortened time outdoors because of road noise	41%	30%
Choose a place to spend time in the garden where there is the least traffic noise	34%	28%
Sometimes refrain from going outside because of traffic noise	39%	26%
Have shortened time outdoors because of traffic noise	41%	30%

Fewer respondents reported opening windows less often, avoiding sleeping with open windows, choosing outdoor locations according to traffic noise, shortening outdoor stays or sometimes avoiding going outside because of noise. At the same time, more residents reported that they had not made any behavioural adaptations because of traffic noise. This suggests that the project has improved the practical use of both dwellings and outdoor areas, even though noise is still present.

The reported acceptance of the noise situation also improved. The share of residents who considered the noise level at home unacceptable decreased from 57% before the barriers to 38% after implementation, while the share who considered the noise level acceptable increased from 15% to 28%.

Residents' overall attitudes towards the noise barriers were mixed. Positive views were mainly linked to perceived noise reduction and improved use of outdoor areas, whereas negative views were often associated with limited perceived effect, loss of view and the visual appearance of the barriers. The largest group, 46%, neither liked nor disliked the barriers, while positive and negative assessments were almost evenly balanced.

5. Dose-response analysis

Figure 3 shows the dose-response relationship between calculated road traffic noise exposure and the share of residents reporting highly annoyance before and after construction of the noise barriers, compared with the general Danish dose-response relationship for motorway noise from 2016 [6].

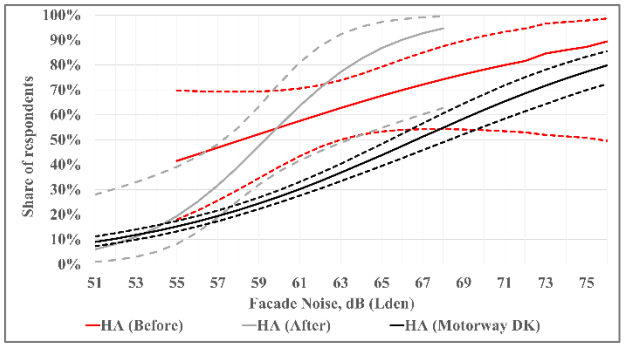

Figure 3. Dose-response relationship for the share of highly annoyed residents before and after installation of the noise barriers, compared with the general Danish dose-response relationship for motorway noise reported in "Noise annoyance from urban roads and motorways" [6].

The dashed lines in Figure 3 indicate 95% confidence intervals; their width reflects the statistical uncertainty in the estimated curves.

The dose-response analysis indicates that residents in Aalborg reported a higher level of annoyance at a given noise level than found in previous general Danish motorway noise study. Before construction, approximately 50% of respondents were highly annoyed at 58 dB (L_{den}), compared with approximately 22% in the general Danish motorway dose-response relationship from 2016. However, the Aalborg results are subject to considerable uncertainty, reflected in relatively broad confidence intervals, and should therefore be interpreted with caution.

It should also be noted that, according to the general Danish dose-response relationship for motorway noise, a reduction of about 5 dB would typically correspond to approximately 18% fewer highly annoyed residents along motorways, depending on the initial noise level and thus where on the dose-response curve the reduction occurs. This is consistent with the Aalborg result, where the average noise level at respondents' dwellings decreased by approximately 5 dB and the share of highly annoyed residents fell by 18 percentage points, from 60% to 42%.

6. Expected and perceived noise reduction

Before construction of the noise barriers, residents were asked about their expectations regarding the noise reduction resulting from the barriers. In the follow-up survey, they were similarly asked about their perceived noise reduction after implementation. Respondents were asked to rate their expectation/perception on a scale from 0 (no noise reduction at all) to 10 (very large noise reduction). Table 4 shows the results for expected and perceived noise reduction.

Table 4. Share of residents reporting the degree of expected and perceived noise reduction before and after installation of the noise barriers

	Noise reduction	
	Expected	**Perceived**
0–3: No/almost no noise reduction	13%	65%
4–7: Moderate noise reduction	33%	21%
8–10: Large noise reduction	45%	9%

Against this background, the survey reveals a substantial gap between expected and perceived noise reduction. Before construction, 45% of respondents expected a large reduction, whereas only 9% reported such a reduction after completion. Conversely, 65% reported no or almost no perceived reduction, compared with only 13% who had expected this outcome before the barriers were built.

Noise barrier projects are typically planned and dimensioned according to whether they can provide a substantial noise-reducing effect for exposed dwellings. Practical indicators are often used to communicate the expected perceptual effect: a reduction of around 5–6 dB is normally regarded as a marked and clearly audible improvement, while 9–10 dB is often described as corresponding approximately to a perceived halving of the noise level.

To examine the relationship between acoustic and perceived effect, the calculated reduction at each dwelling was compared with residents' reported perceived reduction (Figure 4).

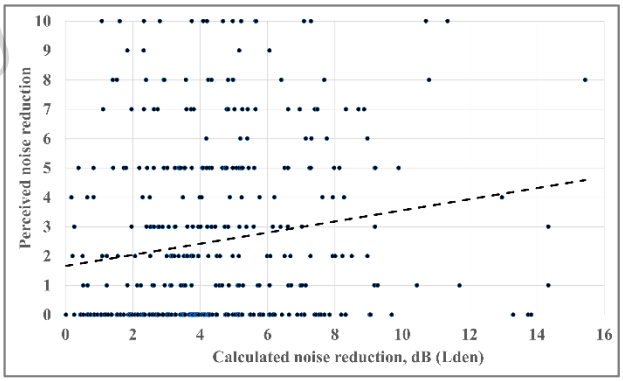

Figure 4. Relationship between calculated noise reduction at the dwelling and the respondent's perceived noise reduction, where 0 = no noise reduction and 10 = strong noise reduction.

Although many dwellings achieved clearly audible calculated reductions, the perceived effect was generally more limited. The figure shows a weak positive tendency: larger calculated reductions were associated with slightly higher perceived reductions on average, but the spread in responses was substantial. The linear regression was statistically significant but weak, with perceived reduction increasing by approximately 0.2 points on the 0–10 scale per additional decibel of calculated reduction. The low explanatory power ($R^2 \approx$

0.03) indicates that calculated reduction explained only about 3% of the variation in perceived reduction.
The large spread in responses indicates that perceived noise reduction is influenced by more than the actual change in noise level. Expectations, changes in the character of the noise, local conditions around the dwelling, the visual presence of the barriers, use of dwelling and garden, and individual noise sensitivity may all affect residents' assessments. Figure 4 therefore illustrates that there is no simple one-to-one relationship between acoustic and perceived effect, although larger calculated reductions tend, on average, to be associated with a more positive experience.
This is consistent with a soundscape perspective, in which the acoustic environment is understood as something perceived and interpreted by people in a specific context, rather than solely as a measured noise level. It should also be noted that residents assessed a change that had taken place over approximately two years. Their responses therefore rely on a comparison between the current sound environment and a remembered pre-project situation, meaning that memory effects and other non-acoustic factors may have contributed to the variation in perceived reductions.

7. Qualitative interviews

The qualitative interviews were conducted as a follow-up to the questionnaire survey to explore why calculated acoustic reductions did not translate into more uniform resident assessments of the project. Twenty-four interviews were carried out with three selected groups of residents:

1. those disappointed despite relatively high calculated reductions,
2. those disappointed and feeling insufficiently informed, and
3. those with a positive attitude towards the barriers.

This design made it possible to explore how similar acoustic changes may be interpreted differently depending on expectations, information, local conditions and everyday use of the dwelling and outdoor areas.
A central finding was that disappointment was not limited to residents with low, calculated noise reductions. Some residents whose dwellings had achieved reductions of 5–8 dB still experienced the project as having little or no effect. For these residents, expectations were particularly important. The scale and cost of the project, together with information and visualisations presented before construction, had created an expectation of a clearly noticeable improvement. When the completed barriers did not meet this expectation, several residents questioned the basis of the project and described the investment as unsuccessful. Some also reported that the noise had changed character rather than simply being reduced, for example becoming more constant, humming or tyre-noise dominated.
For the disappointed residents, the perceived lack of improvement had practical consequences in everyday life. Several described using their gardens less, moving activities to other parts of the property, planning outdoor stays according to wind and weather, or keeping windows and doors closed indoors. In this way, the interviews show that the assessment of the barriers was closely connected to whether residents experienced a tangible improvement in their daily routines, not only to the calculated change in façade noise level.
Information and the experience of the construction phase also shaped the final assessment. Residents who felt insufficiently informed often described both the construction process and the final result more negatively. They asked for more concrete information about the expected consequences for their own dwelling, the timing and extent of construction works, the removal of vegetation, the visual appearance of the barriers and the expected acoustic outcome. For some residents, the removal of trees and shrubs was especially important because it made the motorway more visible and changed the character of the local area. Across groups, the barriers were often described as large, raw or visually dominant, and several residents expressed a wish for planting to soften their appearance over time.
In contrast, residents with a positive attitude towards the barriers generally had more moderate expectations. They did not expect the motorway noise to disappear but described the barriers as having "taken the edge off" the noise and made the sound environment more tolerable. For some, the improvement was experienced directly in everyday life: they could spend more time outdoors, hold conversations in the garden, open windows or ventilate the dwelling more freely. Others did not report a large personal effect but still viewed the project positively because they considered it beneficial for the neighbourhood or for more exposed residents. The positive assessments therefore reflected both perceived acoustic improvement and a more pragmatic understanding of what noise barriers can achieve.
Across the interviews, local conditions were repeatedly used by residents to explain differences between calculated and perceived effects. Variation in barrier height, terminations and openings in the barrier line, bridges, terrain differences and the relative position of dwelling and road were all mentioned as possible reasons why the barriers seemed more effective in some locations than in others. Several residents also emphasised that motorway noise was not experienced in isolation. Other roads in the area, including local arterial roads, contributed to the overall sound environment, meaning that a reduction in motorway noise did not always translate into an equivalent improvement in the total perceived noise situation.
Overall, the qualitative interviews show that residents' evaluations of the project were shaped by the interaction between acoustic change and the local context in which that change was experienced. Expectations, information, construction impacts, visual transformation, vegetation removal, local terrain and

the broader sound environment all influenced whether the barriers were perceived as successful. The interviews therefore support the survey finding that the perceived effect of a noise barrier project cannot be assessed from decibel reductions alone; it also depends on how the change is interpreted and incorporated into residents' everyday experience of their home and neighbourhood.

8. Conclusions

The results also underline the practical limitations of noise barriers along major motorways. Even with high and extensive barriers, it cannot be expected that all dwellings will be brought below the Danish guideline value or that all residents will experience a large improvement. Noise barriers should therefore be understood as an effective but partial mitigation measure, particularly suited to reducing the highest exposure levels rather than eliminating motorway noise entirely.

The evaluation shows that the Aalborg noise barrier project produced a substantial and well-documented acoustic improvement. The number of dwellings exposed above 63 dB Lden was reduced from 490 to 34, and the number above the Danish guideline value of 58 dB Lden was reduced from 1,918 to 591. The average calculated reduction for dwellings above 58 dB before the project was approximately 5 dB, with the largest reductions occurring at the most noise-exposed dwellings. In this respect, the project broadly achieved its acoustic objective of reducing the highest noise levels along the motorway.

This acoustic improvement was also reflected in the questionnaire survey. The share of residents who were highly annoyed by road traffic noise at home decreased from 60% before construction to 42% after completion, a reduction of approximately 18 percentage points. This is in good agreement with the general Danish dose-response relationship for motorway noise, according to which a noise reduction of about 5 dB corresponds to approximately 17% fewer highly annoyed people along motorways. The project therefore demonstrates a notable consistency between the average calculated reduction and the observed change in overall annoyance.

At the same time, the evaluation shows that a clear acoustic effect does not necessarily translate into an equally clear perceived effect for each individual resident. Many residents expected a larger reduction than they subsequently experienced, and the relationship between calculated and perceived noise reduction was statistically significant but weak. The calculated reduction explained only a small part of the variation in perceived reduction, indicating that the residents' assessment of the project was influenced by more than the decibel change alone.

The qualitative interviews help explain this variation. Residents' evaluations were shaped by expectations, information, construction impacts, visual changes, removal of vegetation, local terrain, barrier geometry and the broader sound environment, including noise from other roads. Some residents experienced tangible improvements in everyday life, such as easier use of gardens or open windows, while others experienced limited benefit or changes in the character of the noise. These findings are consistent with a soundscape perspective, where the acoustic environment is understood as something perceived and interpreted in a specific local context.

Overall, the Aalborg project confirms that large motorway noise barriers can deliver substantial reductions in exposure and annoyance at population level, but also that the perceived benefit varies considerably between residents. This evaluation shows that communicating the effects of a noise barrier project is complex: technical indicators such as calculated decibel reductions are important, but they do not by themselves describe how the change is experienced in everyday life. It is therefore essential to align expectations about the likely noise-reducing effects and other project-related changes, including visual impacts, vegetation removal, local conditions and the broader sound environment.

In other words, residents' responses to a noise barrier project arise from the interaction between the physical acoustic change, auditory perception, interpretation of the sound in its local context and the subsequent response, such as annoyance, acceptance or satisfaction.

References

[1] Vejdirektoratet, "Evaluering af støjskærmsprojekt langs Nordjyske Motorvej i Aalborg – Effekter på støjniveau og borgernes oplevelse af støjforholdene", EMN-2026-17517, 2026.

[2] J. Kragh, E. Thysell, P. Finne, F. Pedersen, L. Michelsen and J. Fryd, "The North2000 prediction method for road traffic noise-outline and validation, and application in environmental noise mapping", *JAVA,* vol. 154, Issue 1, pp. 547-555, 2023.

[3] ISO, "Acoustics — Assessment of noise annoyance by means of social and socio-acoustic survey", ISO/TS 15666, 2021

[4] Epinion, "Støjgeneundersøgelse 2025 – Vejdirektoratet", 2025.

[5] Epinion. (2025). "Støjgeneundersøgelse 2025 – Kvalitativ undersøgelse af betydningen af at bo tæt på Nordjyske Motorvej", 2025

[6] Danish Road Directorate, "Noise annoyance from urban roads and motorways. Survey of the noise annoyance experienced from road traffic for residents along motorways and urban roads", Report 565, 2016