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REDUCING THE TRAFFIC INDUCED ANNOYANCE BY PUBLIC PARTICIPATION; INTERACTION BETWEEN QUESTIONNAIRES, MODEL CALCULATIONS, AND MEASUREMENTS

Wim van Keulen[1*]
[1] VANKEULEN advies, Schijndel, the Netherlands

ABSTRACT

Commissioned by a major province in the Netherlands, VANKEULEN advies conducted a study into the annoyance aspects of a main 2-laned road. In 2019, a study was conducted into the complaints and the possible solution(s). Due to its complexity, a step-by-step approach was chosen at the time to quantify the problem based on the path: source - transfer – receiver.
To this end, the first 'subjective' and 'objective' measurements were carried out in 2019. The subjective measurements consisted of a survey among residents, the objective of several measurements on the existing road surface and expansion joints. In addition, noise calculations were carried out. After the application of noise reduction measures (noise barrier, low-noise joints and asphalt), the survey and measurements were repeated in 2022. In this way, the partial effects and the total effect (subjective and objective) of the measures could be determined.
The total noise reduction amounted to 12 – 15 dB(A). The overall nuisance decreased by approximately 50%. At the same time, a significant majority indicated that the overall environmental quality improved. However, the overall appreciation for the high impact of the two measures is surprisingly low.

Keywords: *traffic noise, public participation, noise barriers, low noise pavement, environmental quality*

[*]***Corresponding author***: *info@vankeulenadvies.nl.*

1. INTRODUCTION

On behalf of the Province of South Holland, VANKEULEN Advies conducted a study on noise annoyance associated with the N210 near Rotterdam a road section where numerous complaints were reported to road management authorities in recent years. Significant noise disturbance was documented among residents living along the N210.
In 2019, a global study was initiated to analyse complaints and investigate potential mitigation strategies. Due to the complexity of the issue, a phased approach was adopted, adhering to the framework of **source–transmission–receiver**. Both subjective and objective measurements were conducted in 2019 and repeated in 2022. The subjective assessment involved a survey of residents on both sides of the roadway, while the objective evaluation comprised various assessments of the existing road surface and expansion joints.
Additionally, noise modelling calculations were performed to determine the optimal height for a potential noise barrier and assess its effectiveness. Subsequently, the following noise-reduction measures were implemented:

- 2021: Installation of a noise barrier close to the road, measuring 1.40 meters in height, consisting of a concrete barrier topped with noise-absorbing panels.
- 2022: Application of a noise-reducing thin surface layer.

The follow-up study replicated the pre-measurement assessments to evaluate the individual and cumulative effects (both subjective and objective) of the implemented measures. The total noise reduction at the façades of adjacent residences (relevant for regulatory compliance) and the net noise reduction (relevant for nuisance reduction) were systematically assessed.

2. QUESTIONAIRE

2.1 Questionnaire Design

The questionnaire in 2022 was largely based on the initial survey conducted in 2019. However, in 2022, the primary objective shifted from determining the extent of annoyance to evaluating the reduction of annoyance. The questionnaire was conducted among residents of two sides of the road during September 19 and 22, 2022, concurrently with the noise level measurements. A total of 47 valid replies were collected, of which 24 completed electronically and 23 via postal mail. Statistical analysis indicated no significant differences between the response methods. For comparative analysis, the results were categorised by roadside (south and north) and expressed as percentages.

2.4 Indoor Noise Perception

Tab. 1 presents the results for noise barriers under conditions of closed and open windows.

Table 1. Improvement in Indoor Traffic Noise Due to Noise Barriers [%].

	Closed Windows	Open Windows
High	20	4
Moderate	43	46

Approximately half of the respondents experienced an improvement due to the new noise barrier. Tab. 2 presents the results for quieter asphalt under conditions of closed and open windows.

Table 2. Improvement in Indoor Traffic Noise Due to Quieter Asphalt [%].

	Closed Windows	Open Windows
High	15	7
Moderate	43	48

More than half of the respondents reported improvements due to this measure. Furthermore, the results suggest that the perceived positive effect of quieter asphalt was slightly greater than that of the noise barrier.

2.5 Outdoor Noise Perception

Tab. 3 presents the results for the noise barrier and quieter asphalt in outdoor environments, respectively. The findings indicate a relatively limited impact of the measures in outdoor spaces, except on the north side of the roadway, where the noise barrier had a more pronounced effect.

Table 3. Improvement in Outdoor Traffic Noise [%].

	Noise Barrier	Quieter Asphalt
High	4	9
Moderate	24	39

The quieter asphalt was generally perceived as more effective than the noise barrier.

2.6 Perceived Traffic Noise Annoyance

Tab. 4 presents the results regarding the reduction in traffic noise annoyance due to the noise barrier and quieter asphalt, respectively.

Table 4. Reduction in Traffic Noise Annoyance [%].

	Noise Barrier	Quieter Asphalt
High	9	11
Moderate	37	53

The noise annoyance was reduced by 46% due to the noise barriers, whereas quieter asphalt led to a 64% reduction. Again, the positive effect of quieter asphalt on reducing annoyance was larger.

2.7 Changes in Traffic Noise Characteristics

Tab. 5 presents the results regarding improvements in the perceptual characteristics ("colour") of traffic noise.

Table 5. Improvement in Traffic Noise Perception [%].

	Noise Barrier	Quieter Asphalt
much	13	28
Moderate	49	47

These findings indicate a greater perceived improvement in noise characteristics than the reduction in noise annoyance presented in Tab. 4.

2.8 Overall Improvement

Tab. 6 presents the average improvement in traffic noise perception across different environments.
The average reported improvement in noise perception was 2.3. In summary, while annoyance levels decreased slightly due to the implemented measures, the overall acoustic environment improved for most respondents. However, overall appreciation for the two measures remained relatively low.

Table 6. Average Improvement in Traffic Noise Perception [sca1e 1–5].

Inside	Outside	Area	Total
2.6	2.2	2.1	2.3

3. MONITORING

3.1 Immisions

Monitoring stations were installed at two residential locations, one at the north side and one at the south side. During September 19–22, 2022, concurrent with the survey, noise levels at the two locations were continuously recorded over the course of a workweek. The monitoring results were categorised into daytime, evening, and nighttime periods. These measurements provide insight into the variation of the equivalent continuous sound level (L_{Aeq}) over different short time periods (every 5 minutes). Microphones were positioned at the façades of the residences at both side of the road: northside: 2 m high and southside: 5 m high. These measurement heights correspond to the upper floors where noise-sensitive rooms are located. The monitoring results were compared with those from 2019 to identify relevant differences and potential causes.

3.2 Results

During monitoring, construction activities were ongoing in the vicinity of a patrol station. These activities significantly impacted some measurements (>10 dB(A)); however, these intervals were readily identifiable and accounted for in the analysis. Additionally, the central bus lane had not yet been opened, which led to a slight increase in the influence of bus traffic. However, this effect was found to be minimal. Fig. 1 illustrates the monitoring data obtained from the two locations.

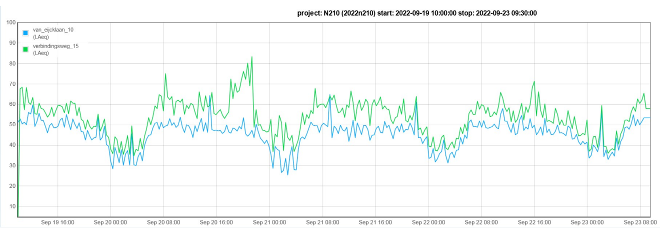

Figure 1. Results of the full monitoring at the two locations.

Tab. 7 provides an overview of the average noise levels for each period. The data have been rounded to the nearest whole number and adjusted for prescribed façade reflection (-3 dB(A)).

Table 7. Average Noise Levels per Time Period [dB(A)].

Location	Day	Evening	Night
North	47	43	34
South	55	49	38

The measured values at south side were higher than those on the north side, primarily due to its closer proximity to the road.

4. NEW ROAD PAVEMENT

4.1 Noise Measurement

A SPB measurement [1] was conducted on September 22, 2022. Tab. 8 presents the measured SPB values for light motor vehicles, along with the strict Dutch reference values.

Table 8. Measured SPB-levels [dB(A)].

Speed	SPB level	reference
50 km/h	63.6	71.0

The noise reduction at the SPB measurement point is approximately 7 dB(A). CPX measurements [2] were conducted on September 11, 2022. Tab. 9 presents the measured CPX values for light motor vehicles.

Table 9. Measured CPX-levels [dB(A)].

Direction	CPX level
East	87.8
West	86.9

By using the calibration relationship between the SPB and CPX measurements conducted in this study, the CPX values were converted into an average SPB level of the entire section as presented in Tab. 10.

Table 10. Average Noise Reductions of the new pavement [dB(A)].

Direction	Noise Reduction
East	7.4
West	8.3

The average initial noise reduction for light motor vehicles travelling at 50 km/h is approximately 8 dB(A). The new expansion joints are not audible and, therefore, not measurable.

5. COMPARISON WITH THE 2019 SITUATION

5.1 Representativeness for the Considered Area

Considering the relatively simple acoustic environment and the symmetry around the road, the results obtained for the two monitoring locations can be generalised to all residences in the vicinity of the road except for a small number of houses located directly behind the petrol station. In this specific area, the full benefit of the quieter road surface is observed, but the influence of the newly constructed noise barrier is minimal.

5.5 Reduction of the immission

Tab 11. shows the average noise immission levels as measured in 2019 and 2022, respectively.

Table 11. Average Noise Immission Levels [dB(A)].

Location	2019	2022	Reduction
North	62	47	14 ± 3
South	68	55	12 ± 3

5.2 Effect of Road Pavement

By comparing noise emissions before and after repaving, the net effect of the new pavement has been quantified (see Tab. 12).

Table 12. Average Noise Reductions before and after Repaving [dB(A)].

Situation	Noise Reduction
Before Reconstruction	1.1
After Reconstruction	7.8

The new pavement results in an approximate noise reduction of 7 dB(A) compared to the previous pavement, which is acoustically equivalent to a fourfold reduction in traffic volume.

5.3 Effect of Noise Barriers

The absolute shielding effect of noise barriers is not easily quantifiable, as it depends on the relative position of the receiver, the noise source, and the barrier. This is because noise barriers primarily attenuate sound via diffraction rather than absorption. When the receiver is located within the acoustic shadow of the barrier, noise attenuation is maximal. However, when the road is directly visible from the receiver's position, the noise attenuation is minimal. The absorptive panels installed on the noise barriers are designed exclusively to prevent reflections that may affect positions on the opposite side of the road. The effect of a noise barrier can be accurately calculated using the Dutch Noise Calculation Method. This method was applied to the two measurement locations based on the actual geometry and placement of the implemented noise barriers (see Tab. 13).

Table 13. Average Noise Reductions before and after Construction of the Barriers [dB(A)].

Situation	Noise Reduction
North	8.5
South	5.5

5.4 Net Subjective and Objective Effect of the Measures

From the data presented in Tab. 12 and Tab. 13 it is evident that the overall noise reduction due to the implemented measures ranged from 12 to 15 dB(A). Notably, the results exhibit a high degree of similarity to those presented in Tab. 11 and in this section. However, as can be seen in Tab. 6, despite the substantial improvements in noise levels and environmental quality, the perceived appreciation of these measures is relatively low.

6. CONCLUSIONS

Based on the findings derived from the questionnaire responses, as well as the noise emission and immission measurements, it can be concluded that, despite achieving a substantial overall noise reduction (>10 dB(A)), the subjective evaluations provided by the residents were only moderately favourable. Furthermore, the research indicates that the level of public participation did not meet anticipated expectations.

7. REFERENCES

[1] ISO 11819-1, "Acoustics -- Measurement of the influence of road surfaces on traffic noise -- Part 1: Statistical Pass-By method", 1997.

[2] ISO 11819-2, "Acoustics -- Measurement of the influence of road surfaces on traffic noise -- Part 2: The close-proximity method", 2017.