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30 YEARS WORKING WITH STRATEGIC NOISE MAPPING: A RETROSPECTIVE IN EUROPE

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Abstract

Since the early 1990s, environmental noise has become increasingly established as a central element of European public health policy. The formal adoption of the Environmental Noise Directive (END, 2002/49/EC) marked a turning point, establishing a common approach to assessing exposure to environmental noise across the EU and requiring Member States to produce Strategic Noise Maps (SNM) every five years for all major roads, railways, airports, and urban areas. Three decades of experience have generated a growing body of knowledge and fresh perspectives, but enduring challenges remain.

From a public health perspective, the urgency of SNM is undeniable. More than 112 million people in Europe are exposed to harmful levels of environmental noise pollution, and road traffic noise contributes significantly to this public health problem in many urban areas. These figures, together with the European Green Deal's objectives of reducing the number of people disturbed by noise, underscore the importance of having harmonized mapping tools.

Methodologically, the harmonization process has been arduous, and it was not until the fourth round of SNM that such process took place, with the CNOSSOS-EU methodology serving as a coherent approach for assessing noise levels from major sources across Europe. This overcame the fragmented national methods that hindered cross-border comparability in the early rounds of the SNM.

The presented retrospective examines the evolution of noise management in Europe across four rounds of SNM: its policy achievements, methodological advances, as well as the gaps that still persist in harmonization.

Keywords: *Strategic Noise Mapping, Europe, Harmonization, Environmental Acoustics, Road Traffic Noise.*

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1. Introduction

Environmental noise occupies a concerned position in the history of European environmental policy. Unlike air or water pollution, whose visible and often dramatic consequences drove early regulatory attention, noise long remained a secondary concern, treated as an inevitable by-product of urban life rather than a public health hazard on its own. This began to change over the course of the 1990s, as a growing body of epidemiological evidence linked chronic noise exposure to annoyance, sleep disturbance, cardiovascular disease, cognitive impairment in children, and broader impacts on mental health and wellbeing [1-3]. What had been a matter of local nuisance regulation gradually became a matter of European public health policy.

The turning point in this trajectory was the adoption of the Environmental Noise Directive (END) in 2002 [4] who did two things that no previous national framework had achieved simultaneously: it

introduced common noise exposure indicators as Lden (day-evening-night level) and Ln (night-time level); it obliged member states to produce Strategic Noise Maps (SNM) every five years for all major roads, railways, airports, and large urban agglomerations. In principle, this created the conditions for a harmonized, EU-wide picture of noise exposure. In practice, as this paper will argue, harmonization has been a slow and uneven process, achieved only partially, and even now leaves significant gaps in the resolution and completeness of the data being produced.

This paper offers a modest retrospective reading of thirty years of noise management in Europe, organized around four related themes. First, it traces the policy trajectory of the END across its four completed mapping rounds, showing how the ambition of a common assessment framework long outpaced the reality of fragmented national practice. Second, it revisits the public health motivation that has sustained political commitment to SNM. Third, it examines the methodological harmonization process that culminated in the mandatory adoption of the CNOSSOS-EU assessment methodology. And fourth, it presents a brief analysis of the four rounds of maps through exposure data for agglomerations for road traffic noise. The analysis presented here comes from data extracted from the EEA geospatial data catalogue on "Noise data reported under Environmental Noise Directive" [5].

2. Policy Framework: The END and Four Rounds of Strategic Noise Mapping

Before 2002, noise policy in Europe was a patchwork of national initiatives, each built on its own calculation method, its own exposure indicators, and its own thresholds for action. France, Germany, and the Nordic countries, among others, had each developed calculation methods (respectively NMPB, RLS-90, and Nord2000) that differed in their treatment of source emission, propagation, and meteorological correction, among others. These differences were not merely technical; they meant that a noise map produced in one country could not be meaningfully compared with a noise map produced in a neighbouring one, even for comparable road types and traffic volumes. Cross-border comparability, and with it any coherent EU-wide assessment of the scale of the problem, was effectively impossible.

The END changed the terms of the debate by mandating common indicators (Lden and Ln) and a common reporting cycle. Under the Directive, Member States are required to produce SNM every five years for agglomerations above a specified population threshold, for major roads, major railways, and major airports. Four rounds of mapping have now been completed: the first around 2007, the second around 2012, the third around 2017, and the fourth in 2022, with data reported to the European Environment Agency (EEA) through 2024. For the first three rounds, however, the common indicators masked a persistent methodological fragmentation: Member States continued to rely on their own national calculation methods to report the common Lden/Ln framework. It was only with the fourth round that this fragmentation was substantially addressed, through the mandatory adoption of the CNOSSOS-EU assessment methodology (discussed in Section 4). The transition was not perfect: the underlying calculation method changed between the third and fourth rounds, the EEA has had to establish an adjusted 2017 baseline specifically to allow valid comparison with the 2022 data, acknowledging that the shift in methodology between mapping years would otherwise make direct comparison unreliable. This detail is worth foregrounding in any retrospective: even the round that finally achieved methodological harmonization required an explicit correction to preserve comparability with everything that came before it. Three decades after the policy's origins, and roughly twenty years after the END itself entered into force, the EU arrived at its first comparable cross-border noise dataset.

3. Public Health Motivation

The public health case for SNM rests on a body of evidence that has only strengthened since the END was adopted. According to the most recent EEA assessment of Round 4, more than one-fifth of Europe's population -around 112 million people- is exposed to transport noise levels exceeding the thresholds established under the END. Applying the stricter guideline values recommended by the World Health Organization (WHO) raises this figure to over 30% of the population. Road traffic is identified as the dominant source of transport noise exposure in both urban and rural areas, ahead of rail and aircraft noise. Together, these findings reinforce the scale of

environmental noise as a persistent public health challenge across Europe [3].

The health endpoints associated with this exposure are now well established in the literature: sleep disturbance and annoyance are the most immediate and best-documented effects, while chronic noise exposure has also been linked to cardiovascular disease and cognitive impairment in children, and with growing evidence indicating broader impacts on mental health and general wellbeing [3]. It is this accumulated evidence that has kept noise on the European political agenda for three decades, and which, for the moment, has culminated in an explicit political commitment within the framework of the European Green Deal's Zero Pollution Action Plan [6], with the objective of reducing by 30% the proportion of the population chronically affected by transport noise by 2030, compared to the 2017 baseline. This objective gives the SNM process a clear evaluative function that it did not previously have: the maps are no longer simply a descriptive exercise, but the measurement tool with which a binding EU policy objective will be assessed. This function, in turn, increases the importance of the data integrity issues documented in Section 5: an objective that depends on monitoring changes at specific exposure thresholds can only be as credible as the data available at those thresholds.

4. Methodological Harmonization: The Road to CNOSSOS-EU

The pre-harmonization landscape was addressed through the development of CNOSSOS-EU, coordinated by the EC Joint Research Centre in cooperation with a Technical Committee of Member State experts, operating under the Commission's Noise Regulatory Committee [7]. The project was conceived as a unified framework for assessing noise from the main categories of sources recognized in the END. Its legal force was established by incorporating an annex to the END. Viewed in retrospect, there is a clear gap between the technical readiness of the CNOSSOS-EU and its mandatory adoption in practice. The methodology was developed and legally incorporated well before the fourth mapping round, but it was not until that round that its use became mandatory for all Member States; two decades passed between the END's original objective of establishing a common assessment approach and the moment when that objective was implemented.

Mandatory adoption did not completely resolve the comparability problem either. Even within the CNOSSOS-EU framework, national implementation decisions continue to introduce variations: for example, recent work by Odeh, Khayyat, and Kocsis [8] documents how different national values for road surface correction factors continue to affect noise emission estimates obtained by different countries using a methodology that is, in theory, the same. Harmonization at the level of the calculation framework has not eliminated the harmonization gaps at the level of the input parameters and correction factors that feed into that framework.

5. Persistent Gaps

5.1 Data source and methodology for the empirical analysis

To move beyond a narrative account of harmonization gaps, this paper draws an analysis of Round 4 exposure data harvested by the EEA through its Reportnet platform [5]. The analysis covers road noise exposure data for different agglomerations across countries with a reporting obligation under the END. For each agglomeration, the dataset records the number of people exposed within seven standard Lden and Ln bands, plus lower bands for the 4th round. Completeness for every band is calculated as the share of all agglomerations for that round (not a pre-filtered subset) that report a numeric value (as opposed to "No data") in that band.

5.2 Findings: a two-layered data gap in round 4

The resulting picture reveals two distinct and analytically separable gaps in the Round 4 dataset, which should not be merged or placed together when interpreting the results. The first is a coverage ceiling; even for the bands with the best reporting (55–59 dB and above for Lden, and 50–54 dB and above for Ln), only 72% of the 435 agglomerations (313 agglomerations) report any data at all. The remaining 122 agglomerations report no exposure data whatsoever, for any band, for road noise. The second, and more specific is a much sharper drop-off at the lowest exposure bands, which occurs even among the 313 agglomerations that reported data. These bands are important for the above-mentioned WHO recommendations [3]. Reporting these lower exposure levels (Lden and Ln), in addition to those highlighted by the END, is necessary to comply with Commission Directive (EU) 2020/367 of 4 March 2020, which amended Annex III of the END to refine the assessment methodologies for evaluating the

adverse impacts of environmental noise, introducing dose-effect relationships by means of adaptations to technical and scientific progress [9]. Among environmental threats to health, transport noise ranks among the top three, surpassed only by air pollution and temperature-related factors. Chronic exposure to this noise is associated with approximately 73,000 premature deaths annually in Europe, as well as contributing to roughly 49,000 new cases of cardiovascular disease [3].

Current information from round 4 show that across the 313 agglomerations, only 11% report a value for Lden 45-49 dB, and 17% report a value for Lden. 50–54 dB; equivalently for Ln. These limitations in the applicability of dose-effect relationships affect the the Noise Action Plans; for it, there is an urgent need to adjust calculations to the valid range of dose-exposure relationships, including data for road traffic noise exposure in agglomerations from 46 dB (Lden) and 40 dB (Ln). The second gap cannot be explained exclusively by non-participation. Most countries appear to possess the modelling capacity to comply with the END's five-year reporting obligation, as they report complete data for every band the END treats as a priority for action planning. The absence of exposure data specifically for the lowest bands reflect a reporting practice in which effort is concentrated on the bands used to support action planning, while the lower bands are not consistently calculated or submitted. A small group of countries, report the lowest bands at or near full completeness, demonstrating that reporting these bands is technically feasible within the CNOSSOS-EU framework. The absence of such data reflects a practical reporting issue rather than a methodological impossibility.

5.3 A four-round longitudinal view of Strategic Noise Mapping in Europe

To situate this historically, this paper extends the same completeness methodology to the three earlier SNM fourth rounds. The four-round comparison is necessarily restricted to the five Lden bands (55–59 dB to >75 dB) and five Ln bands (50–54/55 dB to >70 dB) that exist in all four source files [5]. Table 1 summarizes the resulting coverage.

Table 1. Coverage and reported noise exposure across four SNM rounds: road noise; bands common to all rounds. (*exposed/all agglomeration population, including non-reporting ones) (**exposed/only the population of agglomerations that report data).

Year - Round	2007 - 1st	2012 - 2nd	2017 - 3rd	2022 - 4th
Agglomerations (number)	192	514	422	435
Agglomerations with no data reported (%)	15.6	12.6	12.6	28
Population (million)	128.9	183.28	146.76	148.39
Population uncovered (no data) (%)	4.1	8.5	9.8	19.3
Total population exposed to Lden>55dB* (%)	57.3	39.6	45.5	38
Reporting population exposed to Lden>55dB ** (%)	59.7	43.2	50.5	47
Total population exposed to Ln>50dB* (%)	41.3	28.5	31.3	24.3
Reporting population exposed to Ln>50dB** (%)	43	31.1	34.8	30.1

Treating non-reporting agglomerations as if they contributed zero to the exposed count, by dividing by the “total” population including agglomerations with no data, mechanically deflates the apparent exposure share in exactly the rounds where non-reporting is worst. This is precisely what happens in 2022: 28% of agglomerations, representing 19.3% of the total population in the file, report no data at all on these bands, nearly triple the non-reporting share of the previous rounds. Dividing by total population (the "Percentage of total population" columns) makes 2022 appear to have the lowest exposure share (38% Lden, 24.3% Ln), although a meaningful part of that apparent improvement results from a larger population with unknown exposure contributing to the denominator while no exposure information is available. Dividing instead by only the population of agglomerations that report (the "Percentage of reporting population" columns) narrows the gap considerably: 2022 rises to 47% (Lden) and 30.1% (Ln), much closer to 2011 and 2017 than the total population data suggest. Neither percentage is a fully satisfactory solution on its own, and they should be reported together: the total-population denominator is stable to interpret but penalizes rounds with more non-reporting. With that distinction in place on the reporting-population basis, the share of population

exposed to Lden ≥55 dB moves from 59.7% (2007) to 43.2% (2011) to 50.5% (2017) to 47% (2022). This is a real decline over three decades, but a shallower one than the total-population numbers alone would suggest. Moreover, the four rounds do not share a fixed panel of agglomerations or countries. Reported exposure data reflect overlapping effects that this information cannot fully disentangle: changes in noise exposure, changes in which agglomerations and countries are represented in each round, and changes in how much of the represented population has usable data.

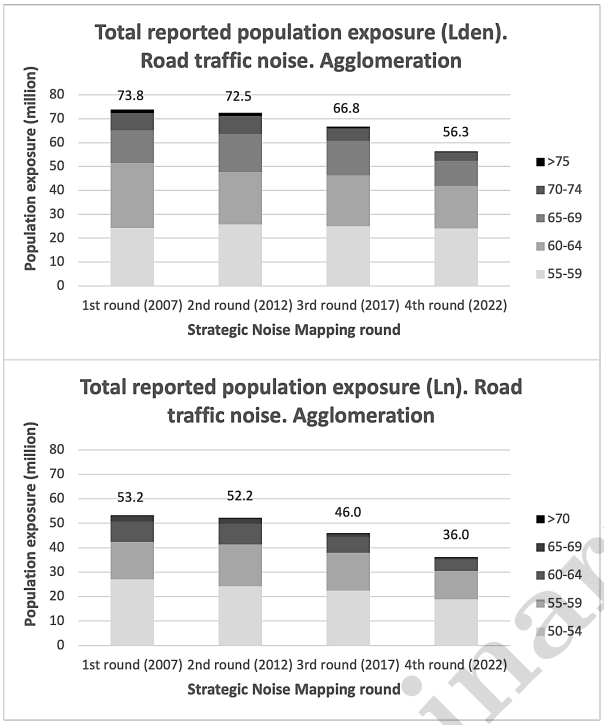

Figure 1. Total reported population exposed by band, to noise (Lden and Ln) in agglomerations from road traffic noise in Europe from reported data in [5].

Figure 1 represents the total reported exposed population by band for each round, making clear that the absolute decline is concentrated in the upper bands (>65 dB). This is expected, as noise action plan tackle the most exposed population. The share-of-population of total and of reporting population from road traffic noise within agglomerations for Lden and Ln, is presented in Figure 2.

It is remarkable that from information in Table 1, 28% of the agglomerations have no data reported for the fourth round, translating this fact in a difference for example, in population exposure (Lden) from third to fourth round going from a 7.5% with no-data reporting to a 3.5% in case only reported data is studied.

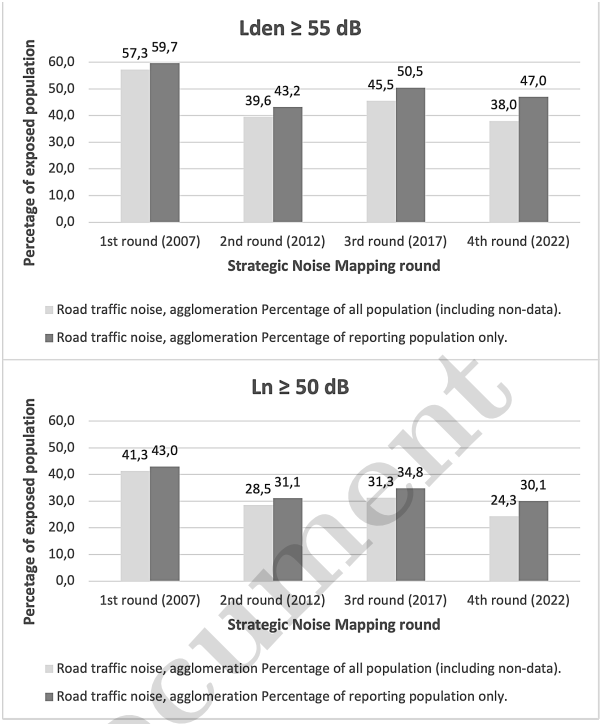

Figure 2. Share of population exposed to noise (Lden and Ln) in agglomerations from road traffic noise in Europe (from reported data in [5]).

5.4 Other structural gaps

The reporting-completeness problem documented above sits alongside several other structural gaps that limit the practical value of the SNM process. Input data harmonization remains incomplete: traffic flow data, vehicle fleet composition, and the resolution of terrain and building data used to model propagation continue to vary considerably between Member States, even where the CNOSSOS-EU calculation core is shared. Reporting delays and inconsistencies across the EEA mechanism compound the completeness problems already discussed [5] since national submissions arrive on a rolling basis over many months rather than as a single synchronized dataset. Industrial and other non-transport noise sources remain comparatively under-addressed relative to road, rail, and air traffic, both in the modelling effort Member States devote to them and in the political attention they receive. The balance between mapping and action planning also remains uneven: mapping obligations of the END are more mature, in institutional and methodological terms, than the action-planning and mitigation side of the Directive. Finally, discrepancies, missing data, etc., which affects the

comparability against which the Green Deal's 2030 target will ultimately be assessed.

6. Conclusion

Three decades on from the point at which environmental noise entered the European public health agenda, and roughly twenty years after the END first legislated for a common assessment framework, this retrospective finds a policy area that has achieved real, if partial, success. The fourth mapping round marks the point at which methodological harmonization finally became a reality for the bands the Directive treats as priorities for action planning. That is a genuine achievement, and one worth stating plainly rather than only critically.

At the same time, this paper's empirical analysis data shows that harmonization at the level of method has not translated into completeness at the level of coverage. Two distinct gaps persist: a straightforward non-compliance gap, in which more than a quarter of reporting-obligation agglomerations submit no exposure data at all; and a more revealing reporting-practice gap, whereby the two lowest exposure bands defined by the Directive are omitted despite the clear capacity to model them and the complete reporting of all higher exposure bands. The second gap matters because is relevant to understand the lower end of the exposure distribution, the population for whom noise remains a nuisance and health risk without yet crossing the thresholds that trigger mandatory action planning, and because a 2030 political target framed around population shares depends on being able to track change at exactly these thresholds.

Looking toward the fifth mapping round and the years beyond, priorities follow directly from this analysis. First, EEA should routinely publish completeness alongside exposure totals, so that aggregate EU figures cannot be mistaken for estimates when large shares of the underlying data are missing. Second, the specific and until now under-documented gap in reporting below 55 dB (Lden) and 50 dB (Ln) deserves attention; thirty years into this policy area, the tools to close these gaps largely already exist; what seems to remain is consistent implementation across participating countries, with particular attention to the reporting of the exposure data needed to apply the dose–effect relationships introduced by Commission Directive (EU) 2020/367 [9].

References

[1] B. Berglund and T. Lindvall, Eds., "Community noise," *Arch. Cent. Sensory Res.*, vol. 2, no. 1, pp. 1–195, 1995.

[2] W. Babisch, "Transportation noise and cardiovascular risk: Updated review and synthesis of epidemiological studies indicate that the evidence has increased," *Noise Health*, vol. 8, no. 30, pp. 1–29, 2006.

[3] European Environment Agency, "Environmental noise in Europe – 2025," EEA Report No. 05/2025, *Publications Office of the European Union, Luxembourg*, 2025. [Online]. Available: https://data.europa.eu/doi/10.2800/5134480

[4] European Parliament and Council of the European Union, Directive 2002/49/EC of 25 June 2002 relating to the assessment and management of environmental noise, Jun. 25, 2002.

[5] European Environment Agency, "Noise data reported under Environmental Noise Directive (END)," *EEA Datahub,* Mar. 19, 2026. [Online]. Available: https://www.eea.europa.eu/en/datahub/datahubitem-view/c952f520-8d71-42c9-b74c-b7eb002f939b

[6] European Commission, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Pathway to a Healthy Planet for All. EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'," *COM(2021) 400 final*, Brussels, 2021. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0400&from=EN

[7] S. Kephalopoulos, M. Paviotti, and F. Anfosso-Lédée, "Common Noise Assessment Methods in Europe (CNOSSOS-EU) – To be used by the EU Member States for strategic noise mapping following adoption as specified in the Environmental Noise Directive 2002/49/EC". *Luxembourg: Publications Office of the European Union*, 2012. [Online]. Available: https://data.europa.eu/doi/10.2788/32029

[8] O. Odeh, A. Khayyat, and D. Kocsis, "CNOSSOS-EU road surface types: Evaluation of the influence of different national values on noise emissions," *Noise Mapping*, vol. 12, no. 1, pp. 58–70, 2025.

[9] Commission Directive (EU) 2020/367 of 4 March 2020 amending Annex III to Directive 2002/49/EC of the European Parliament and of the Council as regards the establishment of assessment methods for harmful effects of environmental noise, Mar. 4, 2020. [Online]. Available: http://data.europa.eu/eli/dir/2020/367/oj