THE CHALLENGES CROATIAN EXPERTS HAVE FACED WHEN USING VARIOUS ROAD TRAFFIC NOISE CALCULATION METHODS BEFORE AND AFTER JOINING THE EU

Tamara Džambas[1], Ana Čudina Ivančev[1], Vesna Dragčević[1], Šime Bezina[2]
[1]*University of Zagreb Faculty of Civil Engineering, Croatia*
[2]*TPA Gesellschaft für Qualitätssicherung und Innovation GmbH, Croatia*

Abstract

Road traffic noise is the second largest environmental stressor in urban areas in Europe after air pollution, and can seriously affect people's health and quality of life. Therefore, valid noise prediction models are crucial for reducing and managing environmental noise and for assessing citizens' exposure to excessive noise levels. Croatia is one of the European countries without national methods for noise calculation. From the outset, Croatian engineers used the German standard DIN 18005 and later the German national calculation method RLS-90 for road traffic noise analysis, which is still widely used in Croatian noise control practice. After joining the European Union (EU), Croatia incorporated the recommendations of the Environmental Noise Directive 2002/49/EC (END) into its national legislation. Consequently, the interim assessment methods and CNOSSOS-EU have been used for strategic noise mapping. This paper provides a brief overview of the basic provisions and revisions of the Directive END over the years, as well as the challenges EU Member States have faced in implementing them. It also describes the challenges Croatian experts have encountered when using various road traffic noise calculation methods before and after joining the EU, presents key results from previous scientific studies that have tested these methods in real environments in Croatia, and discusses the results of strategic noise mapping in the country, with emphasis on road traffic noise. Finally, conclusions on this topic are drawn and recommendations for further research are provided.

Keywords: road traffic noise, noise analysis, strategic noise mapping, Croatia, challenges

1 Introduction

Road traffic is identified as the dominant source of environmental noise, especially in densely populated urban areas, where the largest numbers of people are affected [1]. Chronic exposure to environmental noise significantly affects physical and mental health and well-being [2]. It can cause annoyance, sleep disturbance, cognitive impairment in children, and adverse effects on the cardiovascular and metabolic systems. The number of people exposed to noise from road traffic far exceeds those exposed to rail and aircraft noise, due to the much greater extent of the road network compared to other noise sources. According to the 2025 report of the European Environment Agency (EEA) [3], approximately 69 million people in urban areas and 23 million people outside urban areas are affected by road traffic noise at a level of at least 55 dB during the day-evening-night period. For nighttime noise, the figures are 44 million and 14 million, respectively. This means that 20% of the population during the day-evening-night period and 13% during the nighttime period are exposed to excessive levels of road traffic noise.

DOI: https://doi.org/10.5592/CO/CETRA.2026.1932

In 2002, the European Union (EU) issued the Environmental Noise Directive 2002/49/EC (END) [4] to reduce and manage environmental noise in EU Member States and to establish a common approach for the assessment of exposure to environmental noise in the EU. The END requires Member States to produce strategic noise maps, report the results of this assessment to the European Commission and prepare noise action plans to avoid, prevent or reduce the harmful effects of environmental noise [5]. Furthermore, a key target of the European Commission's (EC) Zero Pollution Action Plan (ZPAP) is to reduce by 30% the number of people chronically disturbed by traffic noise in the EU by 2030, compared with 2017 [6]. According to [3], progress in reducing exposure to harmful levels of noise has been slow, and the EU zero-pollution objective to reduce the number of people chronically disturbed by traffic noise by 30% by 2030 is unlikely to be met without additional measures.
In light of the above considerations, road traffic noise is a serious environmental issue that can significantly affect people's quality of life and health. A reliable estimate of EU citizens' exposure to excessive noise levels is therefore essential for supporting and evaluating noise abatement policy at the European level. This paper provides a brief overview of the basic provisions and revisions of the Directive END over the years, as well as the challenges EU Member States have faced in implementing them. It also describes the challenges Croatian experts have encountered when using various road traffic noise calculation methods before and after joining the EU, presents key results from previous scientific studies that have tested these methods in real environments in Croatia, and discusses the results of strategic noise mapping in the country, with emphasis on road traffic noise.

2 Environmental Noise Directive 2002/49/EC (END)

As mentioned earlier, one of the main objectives of the END [4] was to establish a common approach for assessing exposure to environmental noise in the EU using a set of harmonised noise indicators (L_{den} and L_{night}). EU Member States were required to produce strategic noise maps in accordance with Article 7(1) from 30 June 2007, to enable authorities in EU Member States to set priorities for action planning and to assist the European Commission (EC) in identifying and informing the public about the number of people exposed to excessive noise [7]. Article 6.2 of the END authorised the EC to establish common assessment methods for determining these noise indicators. Pending the adoption of such common assessment methods, EU Member States could use either the interim assessment methods listed in paragraph 2.2 of Annex II of the END or their own national calculation methods. Although it was expected that the national calculation methods of EU Member States would provide similar or identical results to those obtained using the interim methods, the EC found that in most cases these results differ significantly, and that the figures on the number of people exposed to harmful noise levels within and between EU Member States are neither consistent nor comparable [8]. These problems arose mainly from incomplete reporting of strategic noise maps, varying quality and formats of reported data, different assessment methods, differing strategies for selecting, for example, roads to be mapped, and variations in the distribution of populations and dwellings within buildings, etc. [7].
Consequently, in 2008, the EC initiated the development of harmonised methods for assessing noise pollution in Europe through the project entitled "Common framework for NOise aSSessment methOdS (CNOSSOS-EU) [9]. The roadmap for the development and implementation of CNOSSOS-EU included steps in two phases of the CNOSSOS-EU process shown in figure 1: (a) in phase A (2009 - 2012), the CNOSSOS-EU framework was developed based on state-of-the-art scientific, technical and practical knowledge about environmental noise assessment in Europe, together with experience gained during the first round of strategic noise mapping in 2007, (b) in phase B (2012 - 2015), a series of technical tools were developed to support the practical implementation of CNOSSOS-EU in the EU Member States.

Finally, in 2015, an update of END Annex II was published, requiring all EU Member States to use CNOSSOS-EU from 31 December 2018 for strategic noise mapping.

Figure 1 The roadmap for the development and implementation of CNOSSOS-EU

The CNOSSOS-EU method has been evaluated in numerous EU Member States, primarily in those with their own noise calculation methods. The results of these evaluations were presented to the EC and the Noise Regulatory Committee (NRC). In 2018, an EU working group, chaired by the Netherlands and mandated by the NRC, was established to identify and categorise all issues found during these evaluations and ultimately propose the best solutions [10]. Some issues concerned unclear text, which could lead to different interpretations of the method, while others were more fundamental and represented clear errors in the method. For almost all the issues, a solution was drafted.

3 Assessment of exposure to road traffic noise in Croatia

Croatia is one of the European countries without national methods for noise calculation. From the outset, Croatian engineers used the German standard DIN 18005 [11] and later the German national calculation method RLS-90 for road traffic noise analysis [12], which is still widely used in Croatian noise control practice. The first regulations on noise protection in the country were the “Noise Protection Act” [13] and the “Rulebook on the maximum permissible noise levels in environments where people work and live” [14], both published in 1990. Croatia applied for EU membership in 2003 and entered negotiations from 2005 to 2011. On 9 December 2011, EU and Croatian leaders signed the Accession Treaty, and on 1 July 2013, the country became the 28th member of the EU. Accordingly, Croatia incorporated the recommendations of the END into its “Noise Protection Act” of 2003 [15], which required the preparation of noise maps, the designation of critical areas, and the adoption of action plans for noise abatement in places where permissible noise levels are exceeded. Since then, awareness of the problem of noise pollution has grown significantly in this country, and all subsequent regulations in this area have been accompanied by amendments to the END [4] and recommendations from the EC and other relevant EU bodies. As a result, strategic noise maps and action plans were prepared for the second and third reporting rounds in 2012 and 2017, in accordance with the provisions of the new “Noise Protection Act” of 2009 [16] and the “Rulebook on the preparation and content of noise maps and action plans and on the method for calculating permissible noise indicators” of 2009 [17], using the interim assessment methods. In particular, the recommended interim assessment method for road traffic noise was the French national noise calculation method NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB) [18]. Strategic noise maps and action plans for the fourth reporting round in 2022 were prepared in accordance with the provisions of the new “Rulebook on amendments to the Rulebook on the preparation and content of noise maps and action plans and on the method for calculating permissible noise indicators” of 2018 [19], using the CNOSSOS-EU method. The timeline of road traffic noise calculation methods used in Croatia is shown in figure 2.

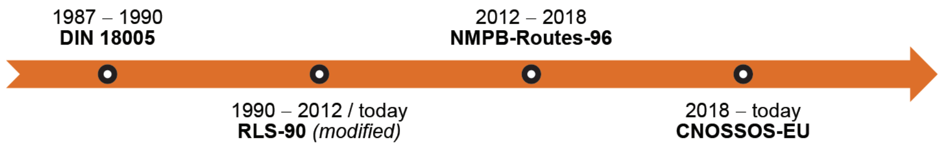


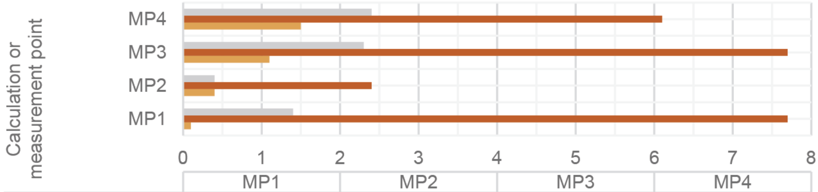
Figure 2 Timeline of road traffic noise calculation methods used in Croatia

3.1 Overview of road traffic noise calculation methods used and results of related scientific studies

The adoption of the first "Noise Protection Act" in 1990 [13] created the need to issue instructions for noise calculation and prediction, as well as for implementing noise protection measures in Croatia, to facilitate the noise protection process prescribed by the Act for noise practitioners at that time. A review of the methods used for noise abatement in European countries then showed two basic approaches to solving this problem [20]: a) countries with developed national noise calculation methods should use these methods for noise protection; b) countries without their own calculation methods could adopt one of the methods from the aforementioned countries that best suited their local conditions. Consequently, Croatian engineers initially used the German standard DIN 18005 [11], and later the German national calculation method RLS-90 [12], for road traffic noise analysis.

The German national calculation method RLS-90 [12] was modified over the years to fully comply with local conditions in Croatia, as well as with applicable Croatian regulations and the provisions of Directive END [21]. These modifications mainly included the following: noise calculations were conducted for three time periods ("day" from 7 a.m. to 7 p.m., "evening" from 7 p.m. to 11 p.m., and "night" from 11 p.m. to 7 a.m.), rather than the two periods defined by the RLS-90 method ("day" from 8 a.m. to 10 p.m. and "night" from 10 p.m. to 8 a.m.); the noise source on multilane roads was placed in the centre of each traffic lane, rather than in the centre of the outer traffic lanes as required by the RLS-90 method; the amount and structure of vehicles, as well as the percentage of heavy vehicles in the traffic flow, were determined based on traffic counting data, rather than on the ADT algorithm in the RLS-90 method, which contains certain parameters applicable only in Germany; the speed of vehicles was defined by field measurements, not as the maximum speed defined by traffic signs as given in the RLS-90 method.

The interim NMPB-Routes-96 method [18] and CNOSSOS-EU [9] have mainly been used for strategic noise mapping and, to a lesser extent, for assessing the impact of new road construction projects on environmental noise, evaluating the effectiveness of various noise mitigation measures, estimating the number of residents exposed to excessive noise levels at specific locations, etc. Numerous studies conducted by the authors of this paper have shown that the noise prediction results obtained using the interim NMPB-Routes-96 method are not sufficiently accurate, while the modified RLS-90 method still provides the most accurate results. In contrast, CNOSSOS-EU is a noise calculation method that has only recently been introduced into Croatian noise control practice, and there has been only one recent scientific study testing this method in real environments in Croatia [22]. The results of this study showed that the difference between the calculated and measured noise levels during the "day" period ranged from 0.4 to 1.5 dB(A) for the RLS-90 method, from 0.4 to 2.4 dB(A) for the CNOSSOS-EU method, and from 2.4 to 7.7 dB(A) for the interim NMPB-Routes-96 method (figure 3).

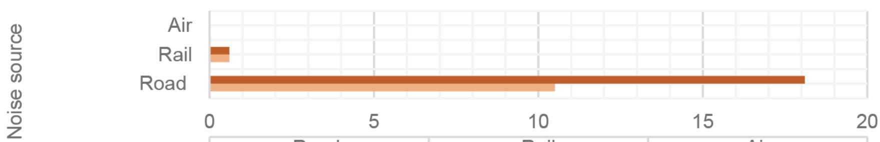


	MP1	MP2	MP3	MP4
CNOSSOS-EU	1,4	0,4	2,3	2,4
NMPB-Routes-96	7,7	2,4	7,7	6,1
RLS-90 (modified)	0,1	0,4	1,1	1,5

Figure 3 Difference between calculated and measured noise levels for the period "day" using different noise calculation methods [22]

3.2 Strategic noise mapping results

The results of the second reporting round of strategic noise mapping in Croatia were not submitted to the EC timely and were therefore not presented in the 2014 EEA report [23]. However, in the third and fourth reporting rounds, Croatia submitted all required data to the EC on time, and the results of the strategic noise mapping for 2017 and 2022 were included in the 2020 [24] and 2025 [3] EEA reports. The data used covered the following noise sources: roads with over 3,000,000 vehicle passages per year, railways with over 30,000 train passages per year, airports with over 50,000 movements per year, and all roads, railways, airports, and industries in urban areas with more than 100,000 inhabitants. The results of the last two reporting rounds of strategic noise mapping in Croatia showed that the noise situation in the country is notably better than in most EU Member States, and that the estimated percentage of people exposed to excessive road traffic noise using the L_{den} indicator is significantly higher (18.1% in 2017 and 10.5% in 2022) than the estimated percentage of people exposed to rail (0.6% in both 2017 and 2022) or aircraft noise (0% in both 2017 and 2022) (figure 4).



	Road	Rail	Air
Lden ≥ 55dB (2022)	18,1	0,6	0
Lden ≥ 55dB (2017)	10,5	0,6	0

Figure 4 Estimated% of people in Croatia exposed to excessive noise levels using the L_{den} indicator in 2017 [24] and 2022 [3]

4 Conclusion

Road traffic noise is a serious environmental issue that can significantly affect people's quality of life and health. Therefore, a reliable noise calculation model is essential for reducing and managing environmental noise and for assessing citizens' exposure to excessive noise levels. The calculation models used to date in Croatia for road traffic noise analysis are as follows: the German standard DIN 18005, the modified German national calculation method RLS-90 (adapted to Croatian local conditions), the interim NMPB-Routes-96 method, and CNOSSOS-EU.

The first two models have been used in everyday noise control practice, while the latter two have mainly been used for strategic noise mapping as recommended by the Directive END. The results of previous studies indicated that the modified RLS-90 the CNOSSOS-EU methods provide significantly more accurate noise predictions compared to the interim NMPB-Routes-96 method. In the "day" period, the difference between the results of noise modeling and noise measurements was from 0.4 to 1.5 dB(A) for the RLS-90 method, from 0.4 to 2.4 dB(A) for the CNOSSOS-EU method, and from 2.4 to 7.7 dB(A) for the interim NMPB-Routes-96 method.

The results of the last two reporting rounds of strategic noise mapping in Croatia showed that the noise situation in the country is notably better than in most EU Member States, and that the estimated percentage of people exposed to excessive road traffic noise using the L_{den} indicator is significantly higher (18.1% in 2017 and 10.5% in 2022) than the estimated percentage of people exposed to rail (0.6% in both 2017 and 2022) or aircraft noise (0% in both 2017 and 2022). However, these figures are likely underestimated and do not reflect the actual number of people exposed to excessive noise levels in Europe. The year 2021, which served as the reference year for the 2022 strategic noise maps, was still affected by the COVID-19 pandemic, with traffic volumes remaining below pre-pandemic levels. As a result, some roads, railways, and airports may not have met the traffic thresholds defined by the END ($L_{den} \geq 55$ dB, $L_{night} \geq 50$ dB) and were therefore excluded from the mapping. Furthermore, the maximum outdoor exposure levels for different noise sources, above which significant negative health effects may occur, as defined by the World Health Organization (WHO), are lower than the reporting thresholds of the END. This creates a knowledge gap regarding the assessment of noise impacts at the European level for values below the END thresholds. Lastly, preliminary analyses suggest that if a broader range of transport infrastructures were considered (roads and railways outside agglomerations with fewer than 3 million vehicle and 30,000 train passes per year, and roads and railways within smaller agglomerations of up to 50,000 inhabitants) the estimates of noise exposure could increase significantly.

In conclusion, when choosing a road traffic noise calculation method, the following should be considered: (1) for creating strategic noise maps, it is essential to use the calculation methods prescribed by the END Directive to ensure comparability of results at the EU level; (2) for noise control in everyday practice, such as optimizing noise barriers, it is advisable to use the calculation method that provides the most reliable noise prediction results to ensure the highest possible efficiency and cost-effectiveness of the protection implemented.

Acknowledgements

This study was conducted within the framework of the institutional project of the University of Zagreb Faculty of Civil Engineering – ENVIRAIL – Development of Advanced Techniques for Noise and Vibration Control on Urban Rail Tracks Using Alternative Materials and Machine Learning Methods, under the programme line for enhancing scientific excellence, financed through the National Recovery and Resilience Plan 2021–2026. The project is funded by the European Union – NextGenerationEU.

The views and opinions expressed are solely those of the author(s) and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

References

[1] Amoatey, P., Omidvarbona, H., Baawain, M.S., Al-Mayahi, A., Al-Mamun, A., Al-Harthy, I.: Exposure assessment to road traffic noise levels and health effects in an arid urban area, Environmental Science and Pollution Research, 27 (2020), pp. 35051-35064, DOI: 10.1007/s11356-020-09785-y

[2] European Environment Agency (EEA): Health impacts of exposure to noise from transport in Europe, https://www.eea.europa.eu/en/analysis/indicators/health-impacts-of-exposure-to-1, 10.12.2025.

[3] Environmental noise in Europe 2025, European Environment Agency (EEA), Denmark, pp.1-151, 2025.

[4] EUR-Lex, an official website of the European Union: Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise, https://eur-lex.europa.eu/eli/dir/2002/49/oj/eng, 01.12.2025.

[5] Environmental Protection Agency (EPA): Guidance Note for Strategic Noise Mapping, https://www.epa.ie/publications/monitoring--assessment/noise/Part-1-Requirements-(May-2025).pdf, 01.12.2025.

[6] European Commission (EC): Zero Pollution Action Plan, https://environment.ec.europa.eu/strategy/zero-pollution-action-plan_en, 11.12.2025.

[7] Kephalopoulos, S., Paviotti, M., Anfosso-Lédée, F., Van Maercke, D., Shilton, S., Jones, N.: Advances in the development of common noise assessment methods in Europe: The CNOSSOS-EU framework for strategic environmental noise mapping, Sci Total Environ, 482-483 (2014), pp. 400-410, DOI: 10.1016/j.scitotenv.2014.02.031

[8] Licitra, G., Ascari, E.: Gden: An indicator for European noise maps comparison and to support action plans, Sci Total Environ, 482-483 (2014), pp. 411-419, DOI: 10.1016/j.scitotenv.2013.07.014

[9] Kephalopoulos, S., Paviotti, M., Anfosso-Lédée, F.: Common noise assessment methods in Europe (CNOSSOS-EU), JCR Reference Reports – Report EUR 25379 EN Publications Office of the European Union, Luxembourg, 2012.

[10] Arnaud, K.: Refining the CNOSSOS-EU calculation method for environmental noise, 48th International Congress and Exposition on Noise Control Engineering – INTER-NOISE 2019, pp. 1-8, Madrid, Spain, 16-19 June 2019.

[11] DIN 18005-1 Beiblatt 1: 1987-05, Berechnungsverfahren; Schalltechnische Orientierungswerte für die städtebauliche Planung, Berlin, pp. 1-35, 1987.

[12] Richtlinien fuer den Laermschutz an Strassen RLS-90: FGSV, Köln, pp. 1-21, 1990.

[13] Croatian Official Gazette: Noise Prot Act (17/90), 1990.

[14] Croatian Official Gazette: Rulebook on the maximum permissible noise levels in environments where people work and live (37/90), 1900.

[15] Croatian Official Gazette: Noise Prot Act (20/03), 2003.

[16] Croatian Official Gazette: Noise Protection Act (30/09, 55/13, 153/13, 41/16, 114/18, 14/21), 2021.

[17] Croatian Official Gazette: Rulebook on the preparation and content of noise maps and action plans and on the method for calculating permissible noise indicators (75/09), 2009.

[18] French Official Gazette: Arrêté du 5 mai 1995 relatif au bruit des infrastructures routières, Article 6: NMPB-Routes-96 (SETRA-CERTU-LCPC-CSTB), 1995.

[19] Croatian Official Gazette: Rulebook on amendments to the Rulebook on the preparation and content of noise maps and action plans and on the method for calculating permissible noise indicators (117/18), 2018.

[20] Lakušić, S., Dragčević, V., Rukavina, T.: Pregled europske regulative o buci od cestovnog prometa, Građevinar, 55 (2003) 6, pp. 349-356

[21] Džambas, T., Dragčević, V., Čuljak, J.: Monitoring of traffic noise on urban road intersection – case study, 5th International Conference on Road and Rail Infrastructure - CETRA 2018, pp. 1203-1208, Zadar, Croatia, 17-19 May 2018.

[22] Džambas, T., Čudina-Ivančev, A., Dragčević, V., Bezina, Š.: Analysis of road traffic noise in an urban area in Croatia using different noise prediction models, Noise Mapping, 9 (2024) 1, pp. 1-17, DOI: 10.1515/noise-2024-0003

[23] Noise in Europe 2014, European Environment Agency (EEA), Denmark, pp. 1-68, 2014.

[24] Environmental noise in Europe 2020, European Environment Agency (EEA), Denmark, pp. 1-104, 2020.