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Research Paper

Tyre Labelled Noise Values in the Context of Environmental Protection: Weaknesses of the Method and Benefits of Silent Tyres

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The purpose of this work was to examine the impact of the inadequacies in the current procedure for car tyre labelling, specifically in the context of environmental noise, and to present the benefits of adopting more realistic procedure with the use of low-noise tyres. This was done using two approaches: an impact analysis and a cost-benefit analysis. The calculations were performed to show this impact on environmental noise. This was done using the common noise assessment methods in Europe (CNOSSOS-EU) model (recommended for strategic noise mapping of EU countries), which was validated using test results from sound exposure level measurements on both ISO test track and on real road sections. Using the noise calculation results, a cost-benefit analysis was performed, incorporating financial analyses of both the current and projected situation under different strategies to reduce tyre/road noise.

Keywords: tyres; tyre noise; road noise; environmental protection; EU tyre label; tyre labelling procedure; traffic noise calculation.

1. Introduction

Vehicle noise is generated by three main sources: powertrain noise, tyre/road noise, and aerodynamic noise. The first source depends on factors related to the load and speed of the engine. The noise level varies with the road gradient, vehicle, speed, and the type of vehicle. Driving style also has a significant influence. Similarly, tyre/road noise is influenced by different factors. In this case, the noise level depends mainly on the type of road surface and tyres. Tyre/road noise increases with vehicle speed (Berge, 2023; Sandberg, Ejsmont, 2002). It is the dominant source of noise at higher speeds, but can still be heard at lower speeds. This is demonstrated by research on the Swiss model sonROAD18 (Heutschi, Locher, 2018), as presented in Table 1. Aerodynamic noise, created by airflow dis-

Table 1. Contribution of tyre/road noise at different vehicle speeds (Heutschi, Locher, 2018).

Speed [km/h]	Percentage of tyre/road noise [%]
30	62.5
40	78.5
50	86.6
60	90.9
80	94.8
100	96.1

turbance, is also a significant component of traffic road noise at higher speeds.

Tyre/road noise is the most significant contributor to traffic noise, making low-noise surfaces one of the most effective noise reduction measures (Bohatkiewicz, Hałucha, 2017; Bohatkiewicz *et al.*, 2022). This noise can also be effectively reduced by using low-noise tyres on vehicles. The proportion of tyre/road noise will increase as the number of electric vehicles increases in traffic flow, as powertrain noise is extremely low at low speeds in electric cars, making tyre/road noise the dominant source. This will be especially important in urban conditions (Hałucha *et al.*, 2023).

The combination of quieter tyres and quieter pavements is the most effective measure to reduce noise in road surroundings (Berge *et al.*, 2022; Berge, 2023). To make such solutions feasible, it is necessary to ensure that consumers have access to information on the noise levels of car tyres. Tyre labels could serve as a valuable tool for this purpose. The European Parliament and the Council introduced Directive on tyre labelling (European Union, 2009) aimed at increasing consumer awareness of car tyres in terms of three main parameters: wet grip, rolling resistance and rolling sound. The new directive (European Union, 2020) introduced several changes, including the current form of the label. The method used to determine the noise level subsequently put on the tyre label is described in Regulation No. 117 (United Nations Economic Commission for Europe [UN/ECE], 2011). This method involves measuring noise during a controlled pass-by of a test vehicle equipped with the test tyres. These tests are conducted on a specially designed surface defined in (International Standard Organisation [ISO], 2021).

Although tyre labels have been on the market for several years, there remains significant uncertainty in the results of tyre labelling (Sandberg, Mioduszewski, 2022). This uncertainty is mainly influenced by the test tyres themselves, variations in the noise properties of ISO surfaces, and the influence of the test vehicle and meteorological conditions, among others. This issue is described in the STEER project (strengthening the effect of quieter tyres on European roads), which was commissioned by CEDR in 2020 and finalised in 2022 (Bühlmann *et al.*, 2022). The project estimated that the uncertainty for C1 (passenger car tyres) and C2 (van and light truck tyres) ranges from 1.4 dB to 2.0 dB, expressed as standard deviations. Such large uncertainties make the labelled data unreliable.

Despite these uncertainties, the tyre labelling system remains an important tool for consumers to select the best tyres. It should be emphasised that external noise is not the decisive criterion for drivers, but it is one of the factors considered (Bühlmann *et al.*, 2022). A survey conducted among consumers in Finland, France, Germany, Italy, Sweden, and the UK (Viegand, 2016) confirmed this fact. The results of this survey are shown in Fig. 1.

Rolling noise is the fourth most important criterion for consumers. The most important criteria for them are wet grip and price. This is also confirmed by the results of survey conducted by Sandberg (2008), in which consumers indicated that wet grip was the most important factor in selecting tyres. It is also worth noting that the price of tyres is not correlated with their noise level (Dittrich *et al.*, 2015; Sandberg, 2008). Therefore, the decision to choose quieter tyres does not directly involve additional costs for consumers. This is an important argument in favour of selecting lower-noise tyres. Additionally, quieter tyres contribute to lower noise levels inside the vehicle, although the correlation in this case is not so high (Bühlmann *et al.*, 2022).

Reducing traffic noise through the use of low-noise tyres can be an effective protection measure. However, this requires ongoing and consistent awareness of the harmful impact of tyre/road noise on the population of the European Union. This awareness is closely linked to the efforts of non-governmental organizations (NGOs) and legislative actions taken by governments and road authorities. These measures could include: reduction or elimination of taxes on the purchase of the quietest tyres, allowing only vehicles equipped with

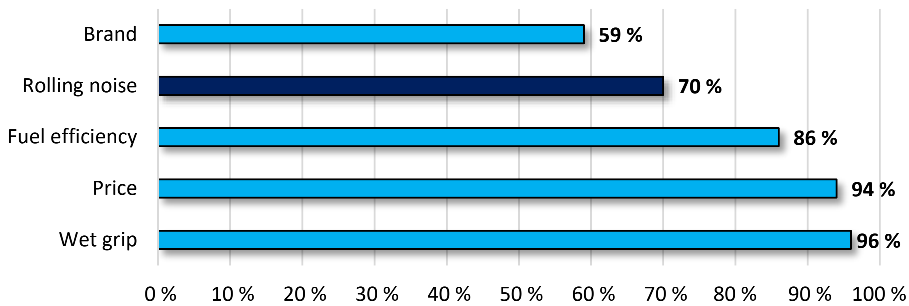

Fig. 1. Importance of specific information on tyre labels for consumers – percentage of respondents who consider the information very important or important (Bühlmann *et al.*, 2022; Viegand, 2016).

quieter tyres to enter selected urban areas (using appropriate chips) or requiring the use of quiet tyres in public administration fleets (Bühlmann *et al.*, 2022).

The tyre industry is also one of the major stakeholders in influencing the use of quieter tyres by consumers. Achieving this would require car tyre manufacturers to enter into an agreement or letter of intent to promote the sale of increasingly quieter tyres, while gradually withdrawing noisier tyres from sale. The STEER project (Bühlmann *et al.*, 2022) proposes that such an agreement should aim to ensure that the total noise level of of all tyres sold does not exceed a predetermined threshold noise limit. Additionally, possible scenarios for reducing environmental noise were proposed in the ELANORE project (Bohatkiewicz *et al.*, 2024).

2. Methodology and input data

First, sound exposure level (SEL) measurements were conducted on both the ISO test track and trafficked sections of roads. A class 1 sound level meter was used, with the FAST time constant and a type A-weighting filter. Test results were stored in the instrument's memory at 1 s intervals. The sound level meter was calibrated with a class 1 acoustic calibrator before and after the measurements. The range of measurements covered four selected car tyres with theoretically different noise levels – their label data were: 67 dB(A), 69 dB(A), 71 dB(A), and 74 dB(A). By comparing these values and the results obtained on the ISO tracks and trafficked roads, it was possible to identify the weaknesses of the procedure described in Regulation No. 117 (UN/ECE, 2011), in relation to environmental noise. To visualise these variabilities, the equivalent sound level (L_{eq}) for a sample road section was calculated.

The next step was to calculate the traffic noise level, with a focus on tyre/road noise. This was done using the CNOSSOS-EU model, which was calibrated using the measurement results, as described in detail in the later part of this section (see Eqs. (3) and (4)). Subsequently, traffic noise was calculated for different types of roads and road surroundings.

To determine the environmental impact of tyre noise (based on labelled data), calculations were made for selected traffic scenarios, using the information provided in the Nordic calculation model NORD 2000 (Kragh *et al.*, 2006). Three vehicle categories are assumed in this model: light – cat. 1, medium – cat. 2, and heavy – cat. 3. Six scenarios were selected for further analysis, as shown in Table 2.

Then, an attempt was made to estimate the noise levels of the tyres currently used by drivers. For this purpose, the data presented in the STEER project report (Bühlmann *et al.*, 2022) were used, with the permission of the Swiss Federal Office for the Environment (FOEN). This is a database containing the C1 tyres approved for sale in Switzerland in 2021. Table 3 shows the number of tyres with a given sound level on the

Table 2. Traffic volume, composition, and vehicle speed on various types of roads based on NORD 2000 model assumptions (Kragh *et al.*, 2006).

Traffic scenario	Description	Traffic volume [V/d]	Composition [%]			Speed [km/h]		
			Cat. 1	Cat. 2	Cat. 3	Cat. 1	Cat. 2	Cat. 3
A	Motorway	20 000	85	5	10	120	90	90
B	Urban motorway	30 000	85	5	10	90	85	85
C	Main road	15 000	85	10	5	85	75	75
D	Urban road	20 000	90	5	5	70	65	65
E	Feeder road in residential area	10 000	95	5	0	50	50	50
F	Residential road	5000	100	0	0	35	35	35

Table 3. Ranking of summer tyres approved for sale in 2021 in Switzerland (Bühlmann *et al.*, 2022).

Group	Sound level range [dB(A)]	Percentage share of tyres on the market [%]	Noise level on the label [dB(A)]	Total number of tyres (n)
Group 1	66–67	2.6	66	11
			67	168
Group 2	68–69	19.7	68	425
			69	967
Group 3	70–72	69.4	70	1881
			71	1695
			72	1326
Group 4	73–75	8.3	73	451
			74	57
			75	81

Source of data: Touring Club Switzerland, financed by the FOEN, https://www.bafu.admin.ch/bafu/en/home.html.

label that were approved for sale. It should be emphasised that these figures relate to summer tyres only. The data were aggregated into four groups with different noise levels.

With the data presented in Table 3, the average sound level was calculated using weighted logarithmic averaging:

$$L_{\text{avg}} = 10 \cdot \log \frac{\sum_{i=1}^{n} (10^{0.1 \cdot L_i} \cdot n_i)}{n} \text{ [dB(A)]}, \qquad (1)$$

where L_{avg} – weighted average sound level [dB(A)], i – sound level value marked on the tyre label [dB(A)], L_i – sound level determined for a tyre with noise value i on the label [dB(A)], n_i – number of tyres with noise values i on the label, n – total number of tyres.

Under these assumptions, the calculated average sound level was 70.8 dB(A). This value was used as the reference level. Then, four different scenarios for improving the acoustic conditions in the road surroundings were identified. One of these scenarios involves withdrawing the noisiest tyres from the market. It is worth noting that some tyres currently available have sound levels that are above or equal to the limits (Bühlmann *et al.*, 2022). To determine the impact of this measure, the weighted average sound level was recalculated, considering only those tyres with a sound level that does not exceed the permissible limits. In this case, the sound level is reduced from 70.8 dB(A) to 70.3 dB(A).

A greater reduction in traffic road noise could be achieved if tyres with noise levels equal to the existing limits were also withdrawn from the market. However, this could be resisted by manufacturers and the automotive industry. After recalculating the weighted average sound level, a value of 69.7 dB(A) was obtained, indicating a noise reduction of 1.1 dB compared to the current situation.

To achieve a greater reduction, it is necessary to take measures to promote quieter tyres among vehicle owners. It was assumed that tyres with noise levels above or equal to the limits would be withdrawn from sale, and the percentage of quieter tyres would increase at the expense of noisier tyres. Two scenarios were assumed. The first was referred to as the sustainable scenario, and the second, the optimistic scenario. The percentages of the individual tyre groups in these scenarios are shown in Table 4.

In the first scenario (sustainable), the weighted average sound level was 69.1 dB(A), resulting in a noise reduction of 1.7 dB. In the optimistic scenario, the average level was 68.5 dB(A). In this case, a reduction in noise level was 2.4 dB.

It should be emphasised that these results were based on sound level calculations, which show the effect of the noise reduction, but do not account for the variability in traffic parameters (such as traffic volume, vehicle speeds, and traffic composition), which affect noise levels. The impact of these parameters was considered in the noise modeling carried out with the CNOSSOS-EU model. In the first step, a calibration of the model was performed for light vehicles (cat. 1) by incorporating an additional factor. Calibration was not conducted for the other vehicle categories (medium and heavy vehicles), because they were not the object of the study.

Table 4. Percentage of tyres for each group under the sustainable and optimistic scenarios.

Group	Percentage share of tyres in sustainable scenario [%]	Percentage share of tyres in optimistic scenario [%]
Group 1 [66 dB(A) – 67 dB(A)]	10	15
Group 2 [68 dB(A) – 69 dB(A)]	55	65
Group 3 [70 dB(A) – 72 dB(A)]	35	20
Group 4 [73 dB(A) – 75 dB(A)]	0	0

To calibrate the model to account for the influence of tyre noise, the CNOSSOS-EU relationship for rolling sound power level calculations was used. For this purpose, light vehicles were assumed to move at a speed v_m of 80 km/h (the reference speed for determining the labelled sound level for C1 tyres). An additional correction factor ΔL_{tyre} was included in the equation, which determines the effect of the noise level of the car tyres, as shown in the equation:

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} \cdot \log\left(\frac{v_m}{v_{\text{ref}}}\right) + \Delta L_{WR,i,m} + \Delta L_{\text{tyre}} \text{ [dB(A)]}, \qquad (2)$$

where $L_{WR,i,m}$ – rolling sound power level [dB(A)], $A_{R,i,m}$ and $B_{R,i,m}$ – coefficients given in the frequency bands for each vehicle category and reference speed [–], v_m – average speed of vehicles in category m (equal to 80 km/h) [km/h], v_{ref} – reference speed, equal to 70 km/h, $\Delta L_{WR,i,m}$ – sum of the correction factors for rolling noise emissions in specific road conditions or for specific vehicles (influence of road surface, studded tyres, traffic lights or junction, temperature) [dB(A)], ΔL_{tyre} – correction factor for the impact of tyre noise [dB(A)].

The ΔL_{tyre} factor in the CNOSSOS-EU model can be assumed for each 1/1 octave frequency band separately (from 63 Hz to 8000 Hz). In this study, the same value is used for each sound frequency. This assumption does not significantly affect the calculation results.

Tyre noise measurements (made using the procedure defined in Regulation No. 117 (UN/ECE, 2011)) and CNOSSOS-EU algorithms consider two sources of noise: rolling noise and powertrain noise. At speeds of 70 km/h to 90 km/h, at which the C1 tyre tests are conducted, the contribution from powertrain noise is small (see Table 1), but it is still present. Therefore, the measurement results include both tyre/road noise and powertrain noise. Similarly, the CNOSSOS-EU model includes both sound sources, as expressed in the following model algorithm:

$$L_{W,i,m}(v_m) = 10 \cdot \log\left(10^{\frac{L_{WR,i,m}(v_m)}{10}} + 10^{\frac{L_{WP,i,m}(v_m)}{10}}\right) \ \text{[dB(A)/m]}, \quad (3)$$

where $L_{W,i,m}$ – directional sound power of one vehicle in category m in the frequency range i (125 Hz to 4 kHz) [dB(A)], $L_{WR,i,m}$ – rolling sound power level [dB(A)], $L_{WP,i,m}$ – sound power level of the propulsion unit noise [dB(A)], v_m – average speed of vehicles in category m [km/h].

The calibration of the CNOSSOS-EU model involved adjusting the correction factor ΔL_{tyre} in such a way that the directional sound power for cat. 1 vehicles across the entire frequency range changed by exactly the amount indicated by the results of the Regulation No. 117 tests (UN/ECE, 2011). This relationship was calculated by regression analysis and is as follows:

$$\Delta L_{W,1}(v_{m=80\ \text{km/h}}) = 0.70 \cdot \Delta L_{\text{tyre}} + 0.06 \ \text{[dB(A)]}, \quad (4)$$

where $\Delta L_{W,1}$ – variation in the sound power of cat. 1 vehicles across the entire frequency range [dB(A)], v_m – average speed of cat. 1 vehicles, equal to 80 km/h, ΔL_{tyre} – correction factor for the impact of tyre noise [dB(A)].

These relationships were obtained using the CNOSSOS-EU method, but they can also be calculated using other methods. The results obtained with contemporary models do not differ significantly (Hałucha, 2023), so the ΔL_{tyre} factor from the CNOSSOS-EU model can also be used directly for other models.

Next, a cost-benefit analysis for selected EU countries was conducted. Noise exposure data for the population, derived from the strategic noise maps, were used for the analyses. These data were taken from (European Environment Agency [EEA], 2024).

First, the number of people exposed to day-evening-night noise (L_{DEN}) levels greater than 55 dB(A) was calculated. The data reported by EU member states after the 2016 strategic noise mapping was used as the baseline scenario. Next, it was calculated how many people would be exposed to the same noise level after the introduction of the previously described scenarios. It should be noted that the data provided by the EEA is divided into 5 dB intervals. The first interval identifies the number of people exposed to noise levels between 55 dB(A) – 59 dB(A), and the last interval to noise levels greater than 75 dB(A). To calculate the number of people exposed to noise within each range after implementing the successive scenarios, it was necessary to approximate the data to narrower 0.1 dB intervals. This approximation was done as accurately as possible, however, the lack of knowledge about the original distribution of people across the 0.1 dB ranges introduces additional uncertainty into the analyses. Nevertheless, this uncertainty is assumed to be negligible.

The number of people exposed to L_{DEN} levels greater than 55 dB(A) was calculated, and the financial benefits of reducing the population exposed to noise were then determined. For this purpose, the environmental costs described in the Handbook on the External Costs of Transport (European Commission, 2020) were used. These costs are related to the annoyance experienced by people exposed to specific noise ranges and the associated health effects. The costs were estimated for 2016, so it is expected that the financial results will be slightly underestimated considering the current situation (2024), particularly due to the high inflation experienced in most EU countries.

3. Impact of surface on tyre labelling in the environmental noise context

One of the main sources of uncertainty in the results of tyre labelling (and often a reason the data on labels may be unrealistic) is the surface on which the tests are conducted as specified in accordance with Regulation No. 117 (Sandberg, Mioduszewski, 2022). It is a specific surface (very smooth) meeting the requirements of the ISO (2021) standard. This issue becomes evident when comparing measurement results for four selected car tyres. First, the results of tests on the ISO test tracks are presented and compared with the data on the labels, which is shown in Table 5.

Measurements were taken on four different test tracks, with tyres 1 and 2 being tested on only two tracks due to unfavourable meteorological conditions that prevented additional tests. The procedure used was described in Regulation No. 117 (UN/ECE, 2011), with all requirements met. The test car was driven at speeds ranging from 70 km/h to 90 km/h. All pass-by noise levels were measured using a sound analyser, two microphones with preamplifiers, a laptop computer, an external radar and a light barrier, all of which held valid calibration certificates.

The average sound level calculated using the data on the labels differs from the sound level derived from real measurements on the ISO test tracks by just 0.3 dB, which is not significant. However, the variability between individual tyres is much more substantial, with differences of up to 3.0 dB for tyres 1, 2, and 4. This shows how unrealistic the data on the labels are.

Table 5. Comparison of the A-weighted average sound level calculated from the label data and the results of measurements on the ISO test tracks.

Tyre	Label values [dB(A)]	Sound level measured on the ISO test tracks [dB(A)]	Calculated label value [dB(A)]	Difference between label and calculated values [dB]
Tyre 1	67	71.4	70	3
Tyre 2	69	73.6	72	3
Tyre 3	71	73.3	72	1
Tyre 4	74	72.9	71	–3
Weighted average sound level	71.0	72.9	71.3	0.3

When using this labelled data for acoustic calculations, it is important to be aware of the significant inaccuracies. This is shown in Fig. 2, which illustrates the results of calculations based on both label data and test data. The calculations were made for an example motorway section (traffic scenario A) and expressed by an equivalent sound level of 60 dB(A).

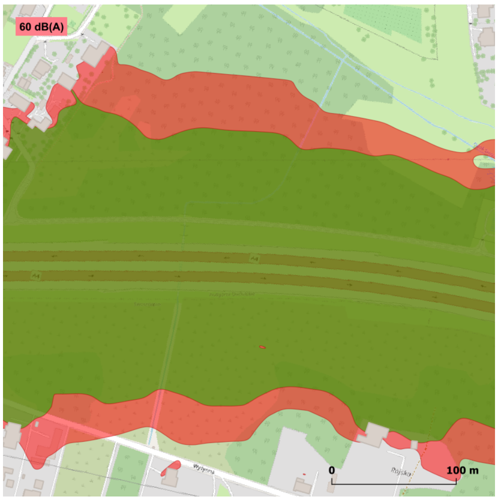

Fig. 2. Results of acoustic calculations using label data (green) and measurement values (red).

These differences reflect the results of measurements conducted strictly according to the Regulation No. 117 procedure on a surface that meets the requirements of ISO 10844 (UN/ECE, 2011). This surface has significantly different acoustic characteristics from those found on trafficked roads. As a result, this differences also impact the sound levels in the environment. This can be observed by comparing the results of measurements made for the same tyres on ISO tracks and typical road surfaces used on trafficked roads (MA11, SMA8, SMA11, SMA16, EACC). These data are shown in Table 6.

The variability range of weighted average sound level from 2.1 dB to 4.2 dB is very high. This can be also seen in Fig. 3, which shows the results of equivalent sound level calculations for the same section of motorway.

Table 6. Comparison of noise levels measured on ISO and typical road surfaces.

Tyre	Sound level measured according to Regulation No. 117 [dB(A)]					
	ISO	MA11	SMA8	SMA11	SMA16	EACC
Tyre 1	71.4	74.6	75.0	76.5	77.7	76.7
Tyre 2	73.6	75.2	76.0	77.0	76.5	75.8
Tyre 3	73.3	75.3	76.4	77.0	76.4	76.3
Tyre 4	72.9	75.0	75.6	76.9	77.8	77.0
Weighted average sound level	72.9	75.0	75.8	76.9	77.1	76.5

Explanations:

- ISO: surface meeting the requirements of the ISO 10844 (UN/ECE, 2011);
- MA11: a Norwegian term for a “soft asphalt” / dense surface with an 11 mm maximum chipping size designed for low traffic volume;
- SMA8, SMA11, SMA16: stone mastic asphalt with maximum chipping sizes of 8 mm, 11 mm, and 16 mm, respectively;
- EACC: exposed aggregate cement concrete.

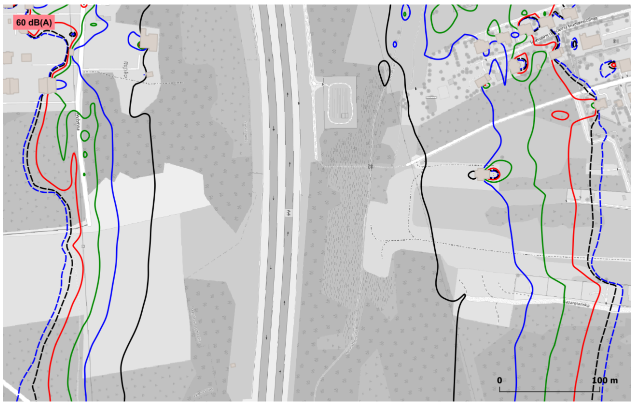

Fig. 3. Comparison of noise levels measured on ISO surfaces and typical road surfaces (black line – ISO, blue line – MA11, green line – SMA8, red line – EACC, black dashed line – SMA11, blue dash line – SMA16).

The sound level calculated for the ISO surface is significantly lower than that for all other real surfaces. The lowest variability is observed for MA11, though it is not widely used (it is used in Norway on roads with very low traffic). Noise levels for the other surfaces, especially for the SMA surfaces (used in many European countries), are much higher than those of the ISO surface currently used for tyre labelling.

An additional problem is the varying ranking of tyres depending on the road surface on which the tests are conducted. For example, tyre 1 is quieter than tyre 2 on the smoother surfaces (such as MA11, SMA8, and SMA11), but noisier on rougher ones (such as SMA16 and EACC) – see Table 6. For this reason, it can be very difficult to choose tyres that consistently produce the lowest noise levels on all surfaces. This challenge would also arise if the reference surface for tyre labelling were changed from the current ISO surface to one of the real-world surfaces.

4. Results of acoustic calculations and cost-benefit analyses for different noise mitigation scenarios

First, it was calculated how the noise levels in the surroundings of different road sections (A – motorways, B – urban motorways, C – main roads, D – urban roads, E – feeder roads, F – residential roads) would be affected by the withdrawal of tyres with noise levels above the legal limit. The noise reduction varied from 0.1 dB up to 0.4 dB depending on the traffic scenario (with the greatest reduction observed on motorways). A greater improvement (from 0.3 dB up to 0.9 dB) was found when tyres with noise levels equal to or above the limit were withdrawn from the market. The results of the calculations are shown in Fig. 4.

Further noise calculations considered the effects of promotional activities aimed at encouraging vehicle owners to choose quieter tyres (see Table 4). The results of these calculations are presented in Fig. 5.

These findings are also illustrated in Fig. 6, which show the results of calculations for individual traffic scenarios on selected road sections in Poland. It shows the differences between the most optimistic scenario (in purple) and the current situation where no actions have been taken (depicted in red). For graphical representation, an isophone of 60 dB(A) was used for traffic scenarios A–E and 55 dB(A) for traffic scenarios F, where the noise level in the road vicinity was below 60 dB(A).

The greatest reduction in noise is observed on motorways, where vehicles travel at the highest speeds. For other types of roads, the improvement is smaller

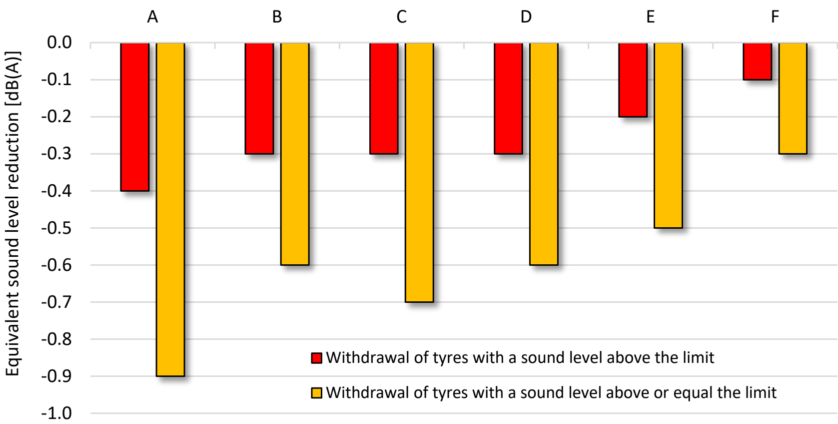

Fig. 4. Reduction in the equivalent sound level after the withdrawal of tyres with noise levels equal to or above the limit.

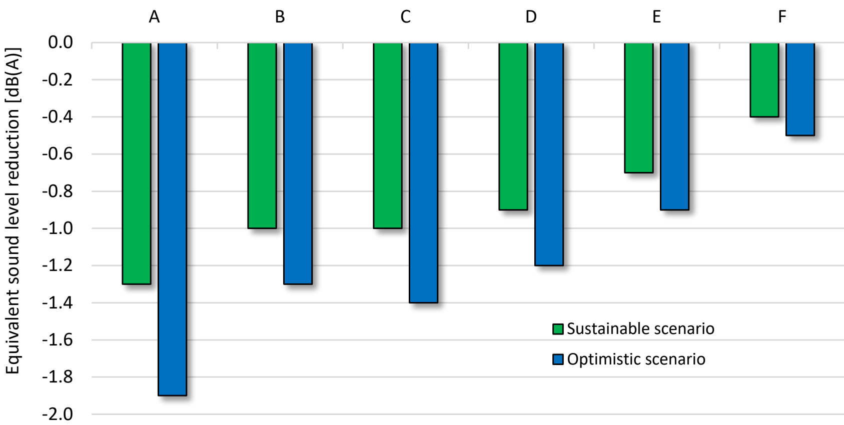

Fig. 5. Reduction in the equivalent sound level considering the promotion of quiet tyres in both the sustainable and optimistic scenarios.

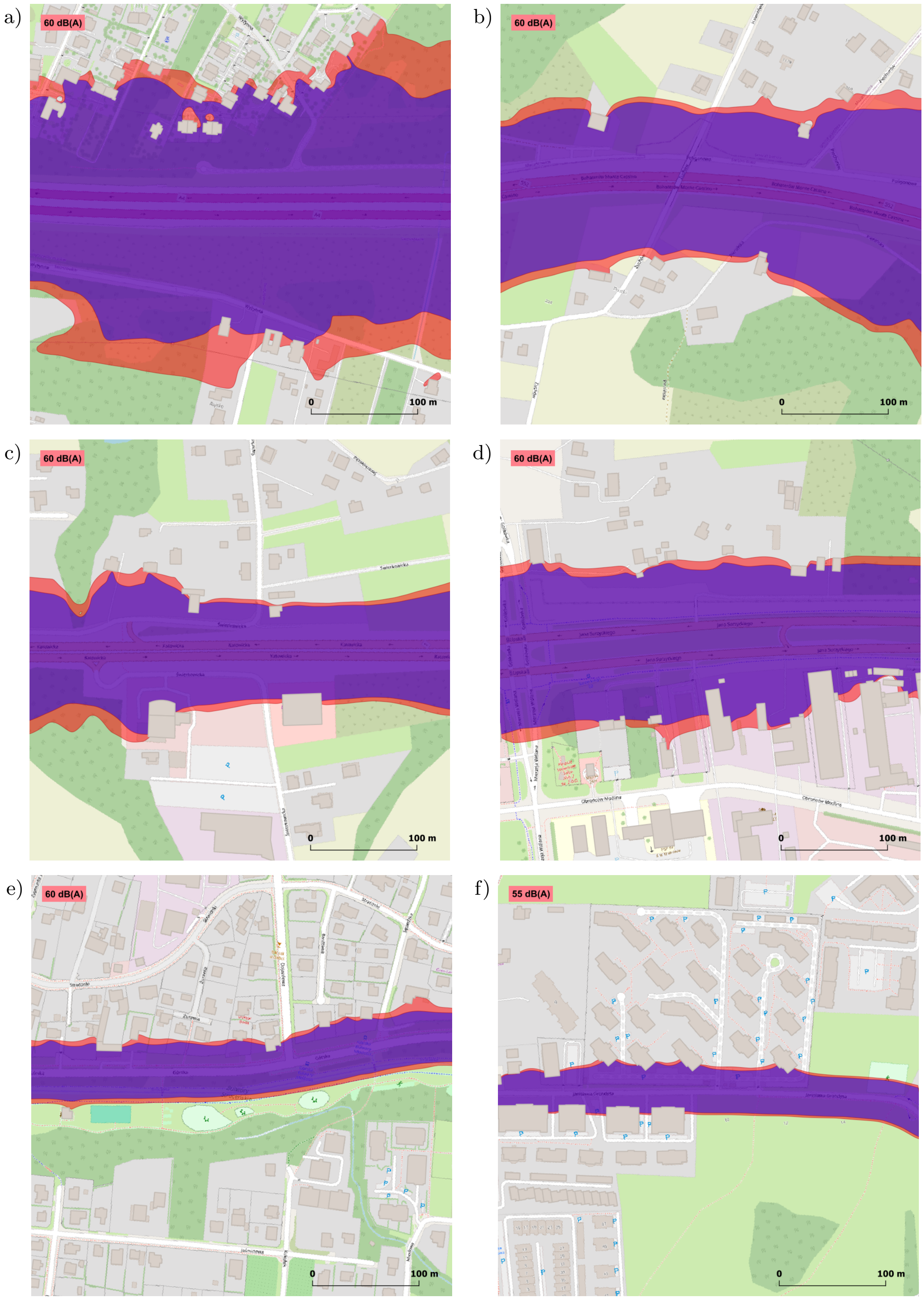

Fig. 6. Reduction in the equivalent sound level for traffic: a) case A – motorway; b) case B – urban motorway; c) case C – main road; d) case D – urban road; e) case E – feeder road; f) case F – residential road.

and it depends on the speed of light vehicles and traffic composition. While the reductions are generally smaller than the measurement uncertainty of ±1.2 dB, they still demonstrate the potential impact these measures can have on environmental noise.

A greater improvement is observed when tyres with sound levels exceeding or equal to the permissible limits are withdrawn from the market. In the case of motorways, this reduction was almost 1 dB. From an environmental point of view, this is a noticeable im-

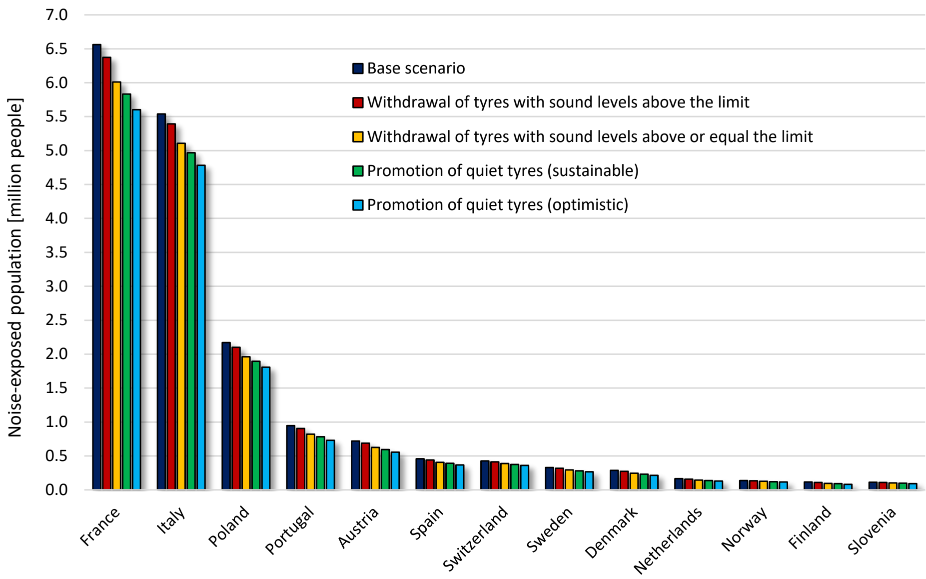

Fig. 7. Comparison of the population exposed to noise above 55 dB(A) in the baseline and noise reduction scenarios (main roads in selected EU countries).

provement. For other types of roads, excluding residential roads, the noise reduction ranges from 0.5 dB to 0.7 dB.

To achieve better results in reducing noise in the road vicinity, further efforts are needed to promote the use of quiet tyres by consumers. In an optimistic scenario, the noise reduction could be significant (over 1.8 dB for motorways). For other roads, the noise reduction is significant, but still noticeable for those living nearby. In all cases, except residential roads, the noise reduction would be greater than 1.0 dB.

Based on the results of noise calculations and the population exposed to noise levels greater than 55 dB(A), it was calculated how the tyre/road noise reduction scenarios would improve the acoustic conditions in the road environment. These improvements are shown in Fig. 7 for main roads in selected EU countries.

The most effective measures are those outlined in the strategies, which include the withdrawal of the noisiest tyres and the promotion of the quietest tyres. In these cases, the reduction in the number of people exposed to noise is significant and noticeable. The introduction of the other strategies also yields a desired effect, although not so high, but still measurable.

The financial benefits were calculated based on the variability of the environmental costs in the baseline scenario and the noise reduction scenarios. These benefits are presented in Fig. 8 showing the gains for the country concerned over a one-year period.

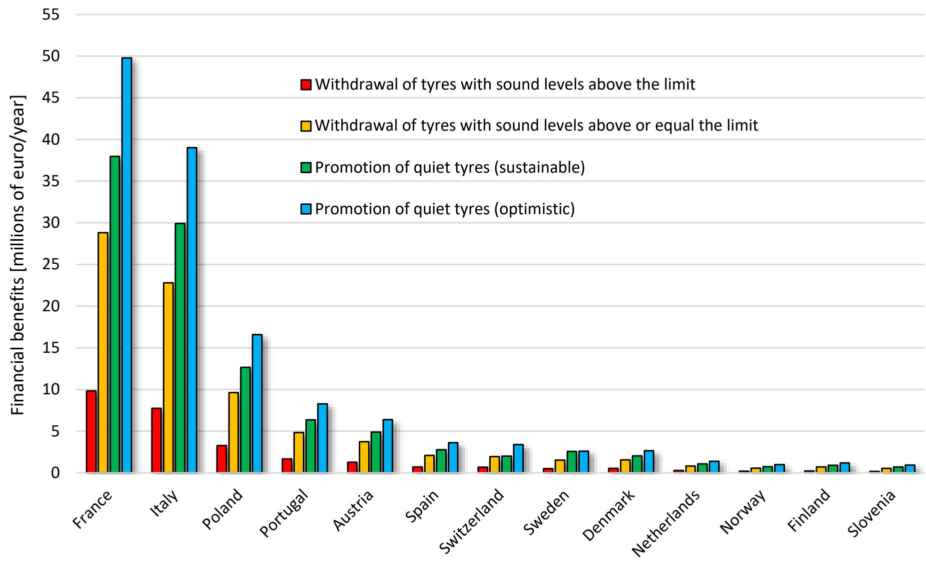

Fig. 8. Financial benefits for one year after implementation of noise reduction scenarios.

The introduction of the analysed scenarios can bring significant financial benefits. For the selected countries, these benefits could amount, in optimistic scenario, to almost €50 million for France, almost €40 million for Italy and more than €15 million for Poland. It should be highlighted that these are benefits for a one-year period, which will be proportionally multiplied in the long term.

The financial benefits were calculated for major roads outside urban agglomerations. No less important are the roads within cities, which were not included in these analyses. In these cases, the noise reduction associated with the use of quiet tyres will be lower due to the lower speeds of cars. However, an improvement in acoustic conditions will still be observed in the surroundings of main roads and motorways in cities. In the ELANORE technical report (Bohatkiewicz *et al.*, 2024), financial benefits were also estimated for selected cities. For example, the annual benefit for Rome is almost €6 million, for Budapest it is more than €4.5 million, and for Prague it is more than €4 million per one year.

Promoting quiet tyres to consumers also incurs costs. At present, it is not possible to make a precise estimate of these costs, because measures to promote low-noise tyres can be implemented on different scales. The necessary financial effort will depend on the scale of the measures taken; however, the costs will certainly be far lower than the financial benefits.

5. Summary

Decreasing the noise level of vehicle tyres is an effective measure to improve environmental acoustic conditions. This is especially important because there is the increasing number of electric vehicles on the road, for which tyre/road noise is the most important source of sound. Encouraging consumers to use low-noise tyres can lead to a considerable reduction in environmental noise. However, it is essential that the data on the labels must be accurate and reflect the noise characteristics of tyres on surfaces commonly used on roads.

The procedure described in Regulation No. 117 (UN/ECE, 2011) is currently used for tyre labelling. However, it is characterised by high uncertainties due to, e.g., the influence of the road surface on which the tyres are tested (along with other factors not studied in the article, including variations in test tyres, the influence of the test vehicle, meteorological conditions, and more). The results of testing four selected car tyres using this procedure indicated differences between the label data and the calculated values based on measurements from the ISO test track. The variability of the weighted average sound level was 0.3 dB, which is not a large difference. More importantly, the differences for individual tyres, in some cases, reached up to 3.0 dB. This shows the inaccuracy of the current label data, which very often fail to reflect the real noise level of the tyres.

The results of measurements and calculations show that tyre noise levels vary according to the road surface. First, it should be emphasised that the ISO surface used for the labelling has acoustic characteristics that differ significantly from those of other surfaces used on trafficked roads. The weighted average sound level calculated for the four tested tyres tested on the ISO surface differs from that on the other pavements by from 2.1 dB to 4.2 dB. In each case, the sound level measured on the test track is lower than that measured on the real road sections. The smallest variability was observed for the MA11 pavement (a very smooth asphalt surface), which is not widely used on roads in European countries. The variability between the sound level measured on the ISO and rougher pavements (e.g., SMA11 or SMA16) is more than 4.0 dB. From an environmental perspective, this is a very large discrepancy.

More important is the fact that the same tyres produce different noise levels on different real surfaces. The maximum variability of the weighted average sound level is 2.1 dB (between MA11 and SMA16). The ranking of tyres also varies depending on the road pavement. For example, tyre 1 is quieter than tyre 2 on smoother surfaces (MA11, SMA8, and SMA11) but noisier on rougher ones (SMA16 and EACC). This has a direct impact on the precision of environmental noise calculations. These results indicate that vehicle tyre labels are biased by additional inaccuracies due to the varying characteristics of typical road surfaces. The same tyre may be quieter on one road surface and noisier on another.

It is not possible to eliminate most of the uncertainty components of the current procedure. Therefore, replacing it with another measurement method should be considered. For example, a laboratory method using drums equipped with a replica of the road surface appears to be a promising direction. Similar methods are already used to measure tyre rolling resistance. Consideration should also be given to equipping these drums with replicas of real pavements (e.g., SMA11 or AC11), which are widely used in most EU countries.

Despite these differences, efforts should be made to reduce the noise level of tyres and to promote those with low noise on the most widely used surfaces. The results of equivalent sound level calculations for selected road sections, varying traffic parameters (from motorway to residential road), showed that this is an effective noise reduction measure. Withdrawing vehicle tyres from the market with sound levels above the permissible limits can reduce noise by 0.4 dB on motorways to 0.1 dB on residential roads. This reduction could be significantly increased by lowering the permissible limits and promoting low-noise tyres to consumers. In this case (optimistic scenario) environmental noise could be reduced by 1.8 dB on motorways to 0.5 dB on residential roads. For all other road categories in this scenario, the noise reduction is greater than 1.0 dB. This is a significant improvement in the acoustic conditions around roads. In addition, it is a source-based action, which is always characterised by high efficiency.

Decreasing environmental noise exposure also results in a reduction in the number of affected people. Based on data taken from the strategic noise maps, it was calculated how many fewer people would be exposed to noise levels in the 55 dB(A) noise range after the introduction of the measures described in the article. For the countries with the largest populations exposed to adverse noise impacts (among those selected for the analyses), highly beneficial effects were observed with the implementation of the different strategies. The most prominent examples are France and Italy, where the number of people exposed to noise above 55 dB(A) can be reduced by almost one million people. Reducing the exposure of the population to excessive noise brings significant financial benefits. These are estimated at nearly €50 million for France, almost €40 million for Italy, and more than €15 million for Poland. These benefits are for a one-year period, which will be multiplied proportionally in the long term. Reducing the noise of car tyres is thus justified from an economic point of view as well.

The use of low-noise tyres is very important in terms of environmental protection. Withdrawing the noisiest tyres from the market and promoting low-noise tyres can significantly reduce environmental noise. A necessary condition for achieving this is to improve the labelling system for car tyres so that the data presented on the labels are as realistic as possible.

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References

1. Berge T. (2023), Technical report on CPX, CPB and SEL measurements. Discussion on selected noise results for improvement of the test method, *Elanore*, https://elanore.mech.pg.gda.pl/en/documents/open-documents.

2. Berge T., Mioduszewski P., Bohatkiewicz J., Hałucha M. (2022), Final report on the noise measurement on ISO reference surface and on conventional pavements, *Elanore*, https://elanore.mech.pg.gda.pl/en/documents/open-documents.

3. Bohatkiewicz J., Hałucha M. (2017), The impact of quiet pavements' usage on traffic noise on people in loosely built-up areas, [in:] *Traffic Noise: Exposure, Health Effects and Mitigation*, Łucjan C., Gerard D. [Eds], pp. 105–205, Nova Science Publishers, New York.

4. Bohatkiewicz J., Hałucha M., Świątek Ł., Drach M., Tyksińska G., Woźniak Ł. (2024), Impact of the new tyre labelling method on the analyses of environmental noise in the vicinity of a road (Technical Report TR19-ELANORE-EKKOM-01), *Elanore*, https://elanore.mech.pg.gda.pl/en/documents/open-documents.

5. Bohatkiewicz J., Hałucha M., Dębiński M., Jukowski M., Tabor Z. (2022), Investigation of acoustic properties of different types of low-noise road surfacers under in situ and laboratory conditions, *Materials*, **15**(2): 480, https://doi.org/10.3390/ma15020480.

6. Bühlmann E., Sandberg U., Berge T., Goubert L., Schlatter F. (2022), *Call 2018 Noise and Nuisance STEER Project Final Report, CEDR Contractor Report 2022-07*, https://www.cedr.eu/docs/view/6373a6fec0dc7-en (access: 15.04.2024).

7. Dittrich M.G., Roo F. de, Zyl S. van, Jansen S.T.H., Graaff E. de (2015), Triple A tyres for cost-effective noise reduction in Europe, [in:] *Proceedings of Euro-Noise 2015*, pp. 2607–2612.

8. European Commission (2020), Handbook on the external costs of transport, Version 2019 1.1, https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1/language-en (access: 15.04.2024).

9. European Environment Agency [EEA] (2024), Noise data reported under Environmental Noise Directive (END), https://www.eea.europa.eu/en/datahub/datahubitem-view/c952f520-8d71-42c9-b74c-b7eb002f939b (access: 27.02.2024).

10. European Union (2009), Regulation (EC) No. 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009R1222 (access: 15.04.2024).

11. European Union (2020), Regulation (EU) 2020/740 of the European Parliament and of the Council of 25 May 2020 on the labelling of tyres with respect to fuel efficiency and other parameters, amending Regulation (EU) 2017/1369 and repealing Regulation (EC) No. 1222/2009, https://eur-lex.europa.eu/eli/reg/2020/740/oj (access: 15.04.2024).

12. Hałucha M. (2023), Differences in the results of road noise calculations made using different models used in European countries, [in:] *The Proceedings from the 27th World Road Congress*, Prague, Czech Republic.

13. Hałucha M., Bohatkiewicz J., Mioduszewski P. (2023), Modelling the effect of electric vehicles on noise levels in the vicinity of rural road sections, *Archives of Civil Engineering*, **69**(3): 573–586, https://doi.org/10.24425/ace.2023.146098.

14. Heutschi K., Locher B. (2018), *SonROAD18 – Calculation model for road noise* [in German: SonROAD18 – Berechnungsmodell für Strassenlärm].

15. International Standard Organisation [ISO] (2021), *Acoustics – Specification of test tracks for measuring sound emitted by road vehicles and their tyres* (ISO Standard No. 10844:2021), https://www.iso.org/standard/80557.html.

16. Kragh J., Jonasson H., Plovsing B., Sarinen A., Storeheier S.Å., Taraldsen G. (2006), User's Guide Nord2000 Road, https://forcetechnology.com/-/media/force-technology-media/pdf-files/projects/nord2000/nord2000-users-guide-road.pdf (access: 15.04.2024).

17. Sandberg U. (2008), Consumer label for tyres in Europe (Report), Swedish National Road and Transport Institute (VTI), Linkoping, Sweden, https://www.transportenvironment.org/discover/consumer-label-tyres-europe/.

18. Sandberg U., Ejsmont J.A. (2002), *Tire/Road Noise Reference Book*, Informex, Sweden.

19. Sandberg U., Mioduszewski P. (2022), The EU tyre noise label: The problem with measuring the noise level of only a few of all tyre variants, [in:] *Proceedings of Inter-Noise 2022*.

20. United Nations Economic Commission for Europe [UN/ECE] (2011), Provisions concerning the approval of tyres with regard to rolling sound emissions and to adhesion on wet surfaces and/or to rolling resistance, Regulation No. 117 of the Economic Commission for Europe of the United Nations.

21. Viegand M. (2016), Final report-review study on the Regulation (EC) No. 1222/2009 on the labelling of tyres, https://energy.ec.europa.eu/publications/review-study-regulation-ec-no-12222009-labelling-tyres_en.