NOISE MAPS OF D1 MOTORWAY

a) Vítězslav Křivánek, a)Petra Marková, a) Jan Machanec, a) Blanka Hablovičová
[a)]CDV – Transport Research Centre, Brno, Czech Republic, vitezslav.krivanek@cdv.cz, petra.markova@cdv.cz, jan.machanec@cdv.cz, blanka.hablovicova@cdv.cz

Abstract: This paper is dealing with the issue of D1 motorway surface(s) modernisation from the noise point of view. The surfaces of the individual sections were consecutively and long-term measured by the CPX method. The four analytical maps of the D1 road surface noise 1) before modernisation (year 2013); 2) after the modernisation (one year after the road section was put into operation); 3) difference map of noise before and after the modernisation; and 4) noise map in 2022 are the results. The analyses and measurement results show that the original assumption of the Road and Motorway Directorate – 2 dB reduction in average noise level after modernisation – has been significantly exceeded. It has also been demonstrated that D1, after the modernisation, had a lower average noise level than the reference (comparative) value specified in TKP 7. Reference value is based on long-term measurements of similar surfaces throughout the Czech Republic.

Keywords: CPX, traffic noise, measurements, acoustic characteristics, noise map, long-term noise monitoring.

1. Introduction

Road traffic noise can have a significant impact on our health. Not only is it annoying but it also disturbs sleep. Research builds on long-established evidence that living in an area with higher levels of traffic noise can lead to stress and sleep disturbances. More recent research shows that this can lead to an increased risk of health problems for residents, such as the development of cardiovascular disease or diabetes [1]. In 2018, the World Health Organization (WHO) released a noise guideline to highlight these issues. The study shows that over 100 million people in the European Union (EU) are affected by road traffic noise. In Western Europe alone, at least 1.6 million healthy years of life are lost as a result of road traffic noise. The extent of environmental noise is huge in terms of health burden, second only to air pollution [2]. The WHO recommendation is that all-day noise from road traffic should not exceed 53 dB (night noise 45 dB), from rail traffic 54 dB (night noise 44 dB) and from air traffic should be below 45 dB (night-time 40 dB). 140 million people in the EU are annoyed by all-day noise (from road, rail, air transport and industry) exceeding 55 dB. The vast majority (113 million, which is over 80%) is affected by road traffic noise [3]. The Strategic Noise Mapping documentation takes into account the age of the pavement concerning its acoustic performance by stating that "the noise properties of road surfaces change with age and level of maintenance, and their noise level usually increases over time" [4]. One way to reduce road traffic noise is to apply a suitable surface and its regular maintenance. A high-quality road surface can significantly help with improving environmental protection also regarding human health and can contribute to the long-term sustainability of transport.

2. Measurement description

The paper deals with the tyre/road noise of D1 motorway surface(s) modernisation in the segment Prague–Brno between EXITs 21–182. The modernisation was performed consecutively in phases. The individual sections were measured using the Close Proximity Method

(CPX). All long-term measurement data were then processed into graphical form as unique noise maps. The data collection, evaluation, and road surface noise analysis were carried out following the mentioned internationally recognised CPX method. It is a dynamic method that is based on measuring the noise close to the reference tyre, which in this case is mounted on a specialised trailer moving on the road. In this way, long segments of roads can be measured and evaluated independently of the intensity of the surrounding traffic flow. It should be emphasised that tyre produces the dominant noise in passenger cars with combustion engines from speeds above 40 km/h. A more detailed description of the CPX method has been presented in a previously published article [5]. Reliable, annually repeated measurements are a prerequisite for a correct influence evaluation of road surfaces on road traffic noise [6].

All measurements were performed using a CPX open trailer developed by the Transport Research Centre (CDV) (Figure 1). The trailer was constructed in 2009 and since 2012, it has been used for regular monitoring of partial acoustic parameters on selected road sections in the Czech Republic. The CPX measurement trailer has met and continues to meet the requirements of ISO 11819-2. Specifically, the condition that the measured total equivalent sound pressure level at the tyre/road contact is at least 10 dB above the maximum measured total disturbance sound pressure level [7].

The Uniroyal Tigerpaw 225/60 R16 SRTT tyre (designated as P1 in ISO/TS 11819-3 [8]) was used for all measurements, as the effect of the measurement tyre used represents the largest uncertainty in the tyre/road noise measurement [9]. It is also recommended in the automotive industry as the standard tyre for ASTM F2493 reference tests. Each year, measurements were performed on a newly acquired reference tyre to minimise the effects of wear and degradation on the tyre itself. The tyre was always used in the period from about April to October. Actual tyre wear was within 0.5 mm of the tread pattern (ISO/TS 11819-3 allows a maximum tread pattern wear of 1.0 mm compared to the initial tread depth) at a mileage of approximately 15 000 km/year. Tyre hardness also needs to be measured and should be within the specified range given by the standard; it is also appropriate to store these reference tyres as recommended [8]. Six measuring microphones are placed in defined positions around the reference tyre P1. Microphones record the sound pressure of the tyre rolling on the road, while other parameters (speed, surface, and air temperature) are measured synchronously. A detail of the microphone arrangement is shown in Figure 1.

Fig. 1: Specialised CDV trailer for CPX measurements (source: CDV).

3. Resulting noise maps

Noise maps were created from the raw data which is the result of long-term measurements using the CPX method at a reference speed of 80 km/h on the D1 motorway before, during and after the modernisation. These are analytical maps with technical content containing information about the noise of individual D1 sections. D1 modernization can be considered a significant road reconstruction project of the decade in the Czech Republic. The first sections were put into operation in 2014, the last in 2021. Concerning the elaboration of the maps presented in this paper, partial results from 2013–2022 were used. Noise maps represent the results analysed from a large number of research projects. No project has lasted as long as the D1 motorway modernisation. In addition, data before and after the actual modernisation are used. This paper presents a noise map before modernisation for 2013 (Figure 2), a noise map of D1 one year after the each road sections was put into operation (Figure 3), a noise map of differences between noise values immediately before and after the modernisation (Figure 4), and noise situation in 2022 (Figure 5).

The results of the acoustic analyses are visualized using GIS (Geographic Information System). ArcGIS Pro software was used for spatial data processing. The tabular data were converted into spatial form using the linear referencing method and appropriately visualized.

Figure 2 shows the noise map of the individual sections of D1 before the modernisation, i.e. in 2013. The resulting values from the measurements of the D1 motorway before the modernisation in 2013 were mostly in the range of 101–104 dB. The value depended on the local condition of the road, where it is possible to find places with better (lower) and worse (higher) noise levels on the map. The average value was then around 102 dB. The noise level reached over 106 dB at the locations with the worst surface. On the other hand, the short segments of D1 that were being repaired before the modernisation had noise levels slightly below 99 dB. The difference in this case between the maximum and minimum values was significant.

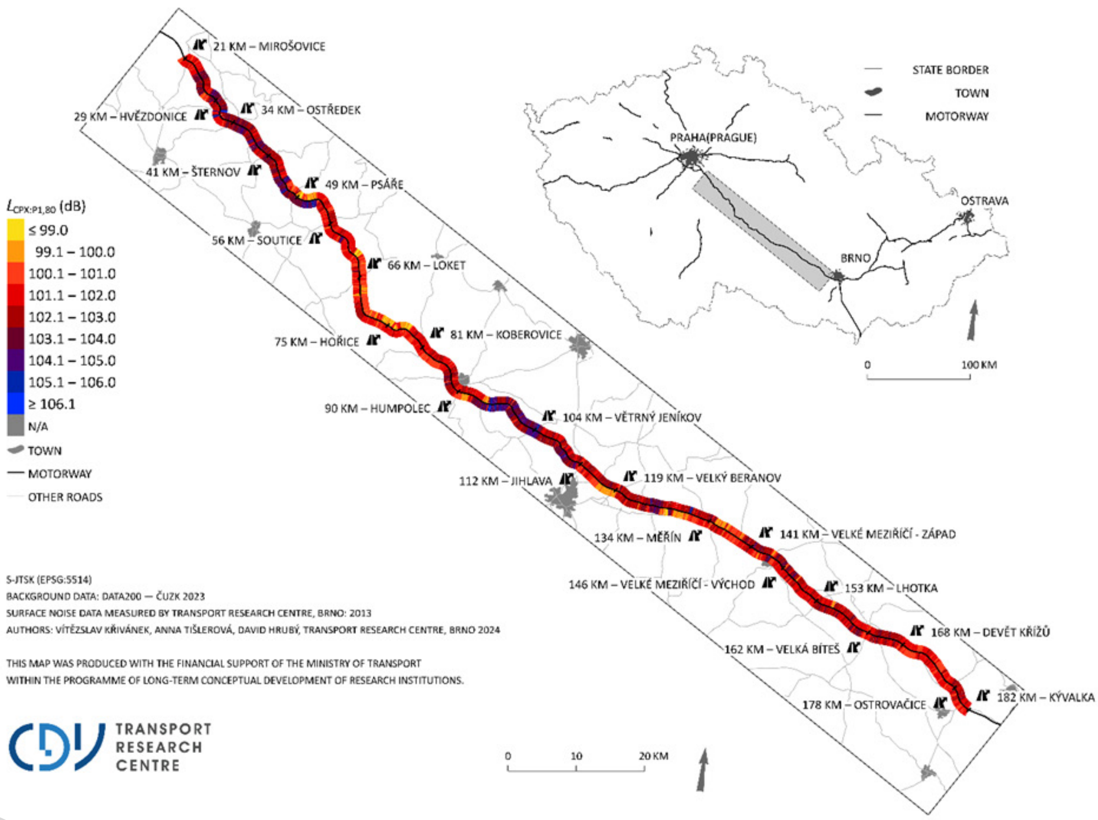
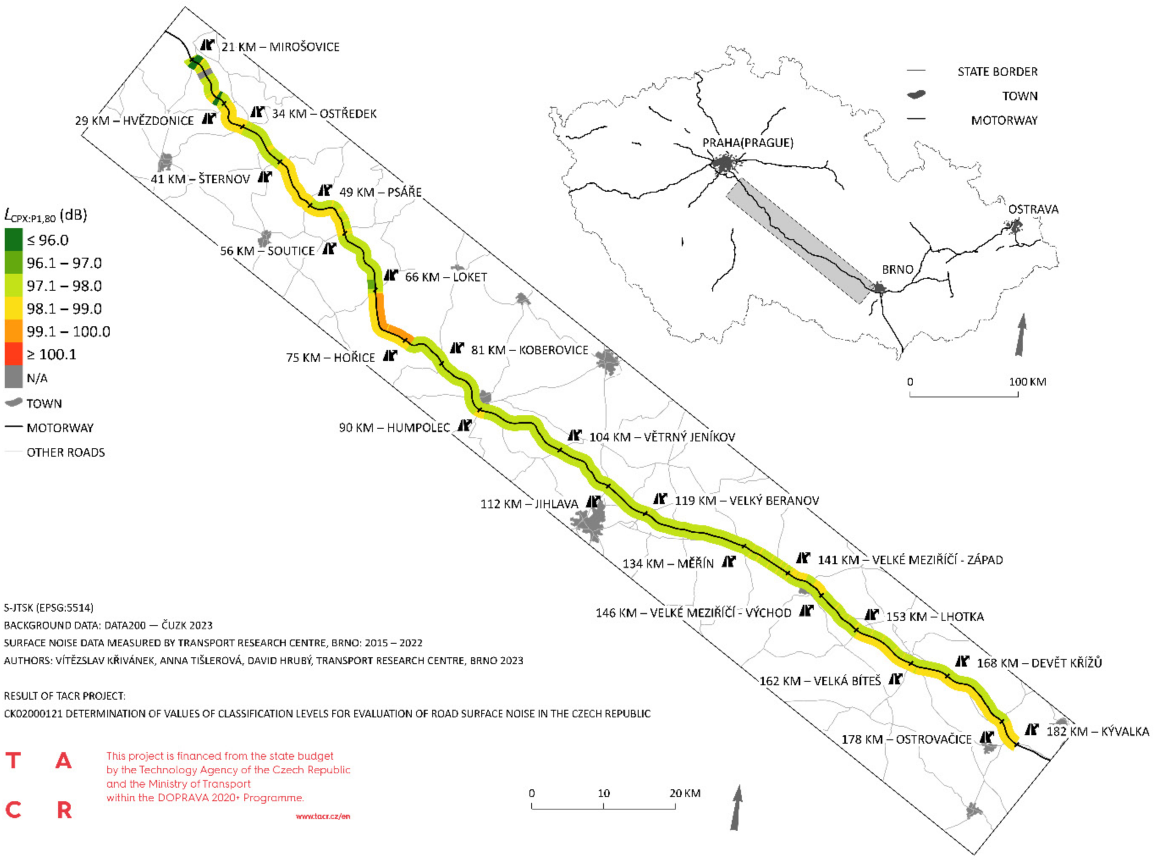


Fig. 2: D1 road surface noise map before modernisation (2013) measured by CPX method [11].

The second map in Figure 3 shows the results of measurements one year after the laying of the new surface in each modernised section of D1. Measurements immediately after putting into operation weren't always possible. Many sections were not put into operation until months when meteorological conditions were no longer suitable for CPX measurements, for example, November or December. The map in Figure 3 is a compilation of measured data from 2015–2022. Each of the sections is represented by the value measured approximately one year after laying, after one winter season. Noise levels were around 98 dB for conventional surfaces. The difference between the maximum and minimum values surface age one year. More details can be found in the Technical Quality Requirements for Road Construction, Chapter 7 Compacted Asphalt Pavement Layers (TKP 7) [12]. The yellow colour in the map corresponds to the average value. Noise levels below the established reference value are shown in shades of green. The orange colour shows the sections with higher noise than the long-term average in the whole country one year after laying. Figure 3 also represents the initial situation after the D1 modernization and thus can be used to compare the increase in noise over time after the modernization, i.e. to compare future measurements made in 5 years.



was within 2 dB, which is also evident on the map in Figure 3. The average noise level on D1 thus corresponds to the established reference (comparative) value for a speed of 80 km/h. It is 98 dB and is equivalent to the average road surface noise of the SMA 11S type measured in situ throughout the Czech Republic using the CPX method – reference tyre SRTT P1 according to ISO 11819-3, speed 80 km/h,

Fig. 3: Noise level of the D1 road surface after modernisation measured by the CPX method on individual sections one year after putting into operation [13].

Figure 4 shows noise map of a difference between noise values of D1 road surface before (2013) and after the modernisation. The post-modernisation noise situation for each section is the value measured one year after putting into operation, see Figure 3. The road surface was replaced or locally repaired before the modernisation began.

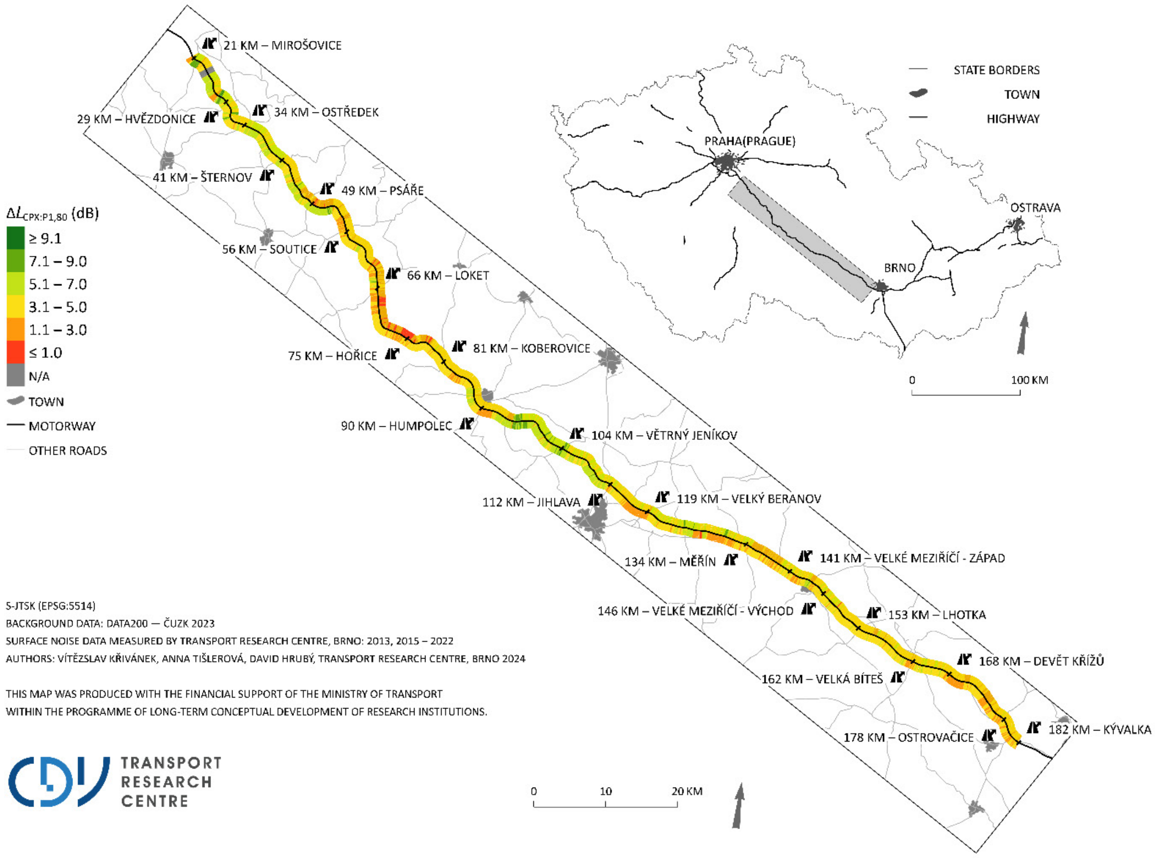


Fig. 4: Difference map of D1 road surface noise before (2013) and after (one year after putting into operation) modernisation measured by the CPX method [11].

owner, Road and Motorway Directorate of the Czech Republic, stated in a press release [14] that it expected an acoustic improvement of 2 dB after the modernisation. The measurement accuracy of the CPX method is ±1 dB. Considering this uncertainty, the expected improvement of 2 dB corresponds to a range of 1–3 dB, symbolised in orange on the map. The average acoustic improvement achieved within segment D1 was predominantly in the 3–5 dB range. This can be seen in Figure 4, where the predominant colour is yellow. Overall, this modernisation exceeded expectations in terms of acoustic improvement. The sections where the noise reduction reached even 9 dB can also be found in Figure 4. Especially in locations of significant road damage or original cement concrete surface unevenness, e.g. slab stepping in a concrete pavement or using a specialised low-noise surface in some areas of the newly modernised D1. However, there are also places where the noise level has been reduced minimally. In these places, the original cement concrete

The actual D1 road surface noise condition after the modernisation in 2022 is shown in the last map in Figure 5. The 2022 noise values for the newest sections, i.e. the last modernised sections, are also used for the partial section in Figure 3. (This map shows the measured values on individual sections one year after putting into operation, i.e. the measurement data for 2022 are used for the sections put into operation in 2021.) The sections with the highest noise levels correspond to the sections modernised first. The highest noise levels, slightly above 100 dB, are shown in red on the map between EXITs 75–66. This corresponds to the fact that the noise level of surfaces evolves and increases over time. Deep green sections can be seen before Prague, which represent low-noise pavements. More than 8 years have passed since the first modernised section of the D1 motorway was put into operation. The modernisation work was carried out in phases. The noise level of the individual sections naturally varies with their age. Thus, the map illustrating the 2022 noise situation (Figure 5) shows more colours than the map demonstrating the situation one year after putting into operation (Figure 3).

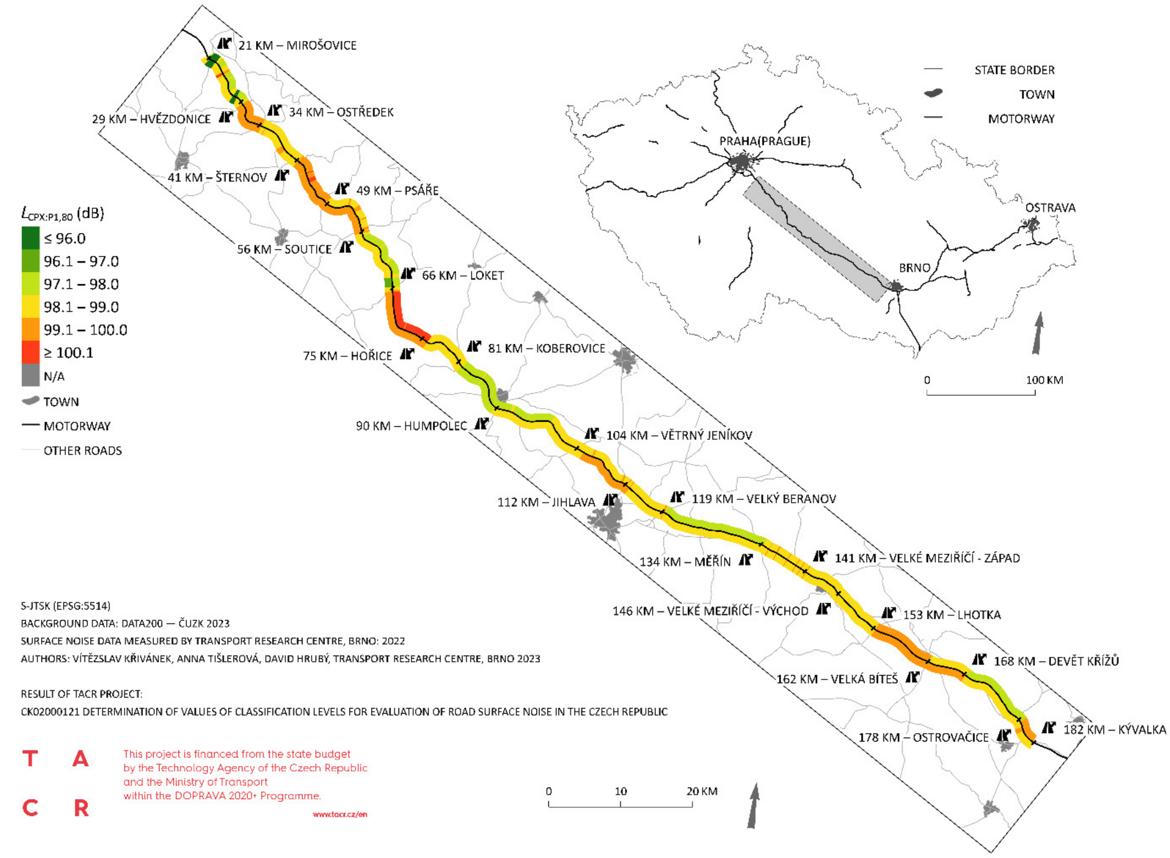


Fig. 5: D1 road surface noise situation obtained by CPX method after the modernisation in 2022 [13].

4. Conclusion

The article is focused on the tyre/road noise levels of the D1 motorway in segment Prague–Brno measured by the CPX method during individual phases of modernisation (2014–2021). The results are noise maps (image visualisation of the analysed data) created from more than 20 million in situ data collected over the last ten years in GIS software.

The noise values measured by the CPX method at the reference speed of 80 km/h on the D1 motorway before the modernisation began were predominately in the range of 101–104 dB, depending on the local road condition. The noise level of the D1 segment is around 98 dB after the modernisation. The predictions of the Road and Motorway Directorate of the Czech Republic before the modernisation assumed an improvement of 2 dB after the completion of the modernisation. The acoustic improvement achieved across the D1 motorway is over 4 dB on average, exceeding initial expectations. This is a significant improvement. It is significant to note the following facts about road traffic noise: "a 3 dB reduction in traffic noise is equivalent to halving the traffic volume at a specific location while maintaining the same ratio of passenger and freight traffic".

In conclusion, the D1 modernisation is a success in terms of noise which is evident from Figure 3. The average noise level of 98 dB corresponds to the established reference value for a speed of 80 km/h and is based on long-term CPX measurements across the Czech

Republic. This average value is achieved on approximately 27 %, a lower noise on 70 %, and a higher noise on 3 % of the measured motorway segment length. The surface of the modernised D1 shows a slightly better noise level than the average noise value of all road surfaces in the Czech Republic. The noise map of the D1 measured by the CPX method one year after putting into operation (Figure 3) will continue to be used for tyre/road noise comparison after the modernisation – it represents the initial for assessing changes over time. The noise increase measured in 2022 compared to the initial is shown in Figure 5. There are more sections marked in orange. This colour represents a value above 99 dB which corresponds to the average noise level of conventional surfaces about five years old and in good condition.

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Ing. Vitězslav Křivánek, Ph.D.,

1981, is a graduate of Brno University of Technology, Faculty of Electrical Engineering and Communication. In his post graduate study in 2005–2008 he participated in research projects of FRVŠ, GAČR, NBÚ, MPO ČR, NPV II. In 2002–2011 he cooperated with a leisure activity centre Junior – DDM in Brno, where he participated in educational and preventive activities concerning free time of children and the youth in the Department of Science and Technology for Everybody. Since 2008 he has been working in Transport Research Centre (CDV) as a researcher in the field of transport environmental aspects. Recently he has cooperated in CDV in R&D projects: "Quantification of external costs of transport in the Czech Republic, Virtual education in transport, Education of youth to sustainable transport, Critical analysis of new materials and new shapes suitable for noise barriers, Tools for Analysis and Assessment of Environmental Impacts of Road Surface Noise, Centre for Effective and Sustainable Transport Infrastructure, Urban planning using low-noise roads". Furthermore, he produces noise studies, expertise in noise from transport, he is a member of an accredited laboratory No. 1506 for measuring traffic noise, and a member in an international work group CEN TC 227 WG5. Since 2021 he is a guarantor of a project "Determination of values of classification levels for evaluation of road surface noise in the Czech Republic".

Ing. Jan Machanec

Ing. Jan Machanec, graduated of a bachelor's degree in 2018 and a master's degree in 2021 at Mendel University in Brno. His thesis was focused on the kinematic of braking forces on hybrid and electric vehicles. He has been working in Transport Research Centre (CDV) since 2021 and he focuses on environmental acoustics. Mainly he deals with measuring by method CPX all around the Czech Republic. He collaborates on projects for the Technology Agency of the Czech Republic as CK02000121 and TL02000258, a project funded by the Ministry of Transport and on the new methodology CNOSSOS-EU.

Ing. Blanka Hablovičová

Ing. Blanka Hablovicova obtained a master's degree from the University of Pardubice in 2013. Since 2018, she has been working in Transport Research Centre (CDV) as a researcher. She deals with traffic noise from the environmental point of view which includes noise generated around roads. She collaborates in projects of the Technology Agency of the Czech Republic CK02000121 and TL02000258; project funded by the Ministry of Transport "Analysis and monitoring of road surface noise changes". She also participates in the (SUMP) of towns and cities in the Czech and Slovak Republic. She also contributes in project "Acoustic properties of the most used surfaces in the Czech Republic and their implementation in the CNOSSOS-EU calculation methodology".

Ing. Petra Marková

Ing. Petra Markova, graduate of Mendel Agriculture and Forestry University in Brno, has been working in Transport Research Centre (CDV) since 2005. Her main activity in the field of transport and the environment is focused on the environmental acoustics. Her work includes assessing acoustic situations around roads, assessing acoustic situations with the use of measurements and numeric noise modelling by software SoundPLAN, and subsequent assessing transport noise impact on population. She is currently involved in a project funded by the Ministry of Transport "Analysis and monitoring of road surface noise changes" and projects of the Technology Agency of the Czech Republic CK02000121 and TL02000258. She participates in project concerning CNOSSOS-EU, classification of surfaces in the Czech Republic. In the frame of "Sustainable Urban Mobility Plans" she processes noise studies. She is also a member of an accredited laboratory for traffic noise measuring.