



PASS-BY NOISE ASSESSMENT OF CONTEMPORARY AND LEGACY RAIL VEHICLES ON SERBIAN RAILWAYS

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Abstract – Pass-by noise represents one of the key environmental criteria in the approval and operation of modern railway vehicles. In addition to vehicle design, the condition of the track and braking technology significantly influence the measured noise levels. During the type testing of a diesel track inspection vehicle on the upgraded Belgrade–Novi Sad railway line, pass-by noise measurements were conducted on various passenger and freight trains under identical, controlled experimental conditions. This setup enabled a direct acoustic comparison between contemporary and legacy rolling stock, including electric multiple units (EMUs), freight trains with different braking systems, and multiple generations of electric locomotives. All measurements complied with the EN ISO 3095:2025 standard, with track acoustic characteristics validated through rail roughness and track decay rate (TDR) assessments. The obtained results demonstrate substantial differences in environmental noise emission between older and modern rolling stock. Notably, freight wagons equipped with cast iron brake blocks generated approximately 9 dB higher pass-by noise than wagons fitted with composite brake blocks. Furthermore, modern electric locomotives exhibited significantly lower noise emissions than their legacy counterparts. These findings underscore the critical role of advanced braking technologies in mitigating railway noise and highlight the environmental benefits of fleet modernization in achieving compliance with current European Technical Specifications for Interoperability (TSI).

Keywords – Railway acoustics; pass-by noise; freight wagons; composite brake blocks; EN ISO 3095:2025.

1. INTRODUCTION

Environmental noise generated by railway traffic has become an increasingly important aspect of railway system development due to stricter European environmental regulations and the continuous modernization of railway infrastructure. Among the different sources of railway noise, rolling noise generated at the wheel–rail interface dominates at medium and high operating speeds and is strongly affected by wheel and rail surface conditions, vehicle design, and braking technology.

Pass-by noise measurements are therefore an essential part of the type approval procedure for new railway vehicles and are standardized by EN ISO 3095:2025. Reliable comparison of vehicle noise performance requires measurements under controlled

acoustic and track conditions, including verification of rail roughness and track decay rate to ensure that the measured noise originates primarily from the vehicle rather than the infrastructure.

The reconstruction of the Belgrade–Novi Sad railway line created suitable conditions for conducting standardized pass-by noise measurements. During the type testing of a diesel track inspection vehicle, additional measurements were performed on passenger trains, freight trains, and electric locomotives operating over the same test section. Since all measurements were carried out under identical environmental and track conditions, the collected data enabled a direct comparison of noise emissions from contemporary and legacy rolling stock.

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Particular attention is devoted to freight trains, where braking technology has a pronounced influence on rolling noise. The comparison between wagons equipped with conventional cast iron brake blocks and those fitted with composite brake blocks provides a practical illustration of the benefits achieved through modern braking systems and supports current European requirements for quieter railway operation.

2. MEASUREMENT CONDITIONS

The pass-by noise measurements were performed on the upgraded Belgrade–Novi Sad railway line during the type approval testing of the diesel track inspection vehicle DV GPK. The test campaign provided an opportunity to measure the pass-by noise of several passenger and freight trains operating over the same track section under identical environmental and infrastructure conditions.

Measurements were carried out in accordance with the requirements of EN ISO 3095:2025. The selected test site was located at km 61+960 of the railway line, where the track fulfilled the acoustic requirements prescribed for standardized pass-by noise measurements. Weather conditions during testing complied with the standard, including the absence of precipitation, low wind speed and sufficiently low background noise.

Since the acoustic characteristics of the track have a significant influence on measured pass-by noise, the test section was characterized before vehicle testing. Rail acoustic roughness was measured in accordance with SRPS EN 15610:2025 using the Müller-BBM *m|rail trolley* system. The measured roughness spectra remained within the permissible limits specified by the standard, ensuring that the rail surface did not introduce excessive rolling noise.

The dynamic acoustic behaviour of the track was additionally verified through track decay rate measurements performed according to EN 15461. Frequency response functions were obtained using an instrumented hammer and rail-mounted accelerometers in both vertical and lateral directions. The measured decay rates satisfied the prescribed acceptance criteria, confirming the suitability of the selected track section for comparable pass-by noise measurements.

During each vehicle passage, the A-weighted sound pressure level was continuously recorded using a calibrated microphone positioned 7.5 m from the track centreline and 1.2 m above the top of the rail. An optical sensor installed at the microphone section detected the wheel passages and enabled accurate determination of vehicle speed together with the beginning and end of the measuring interval.

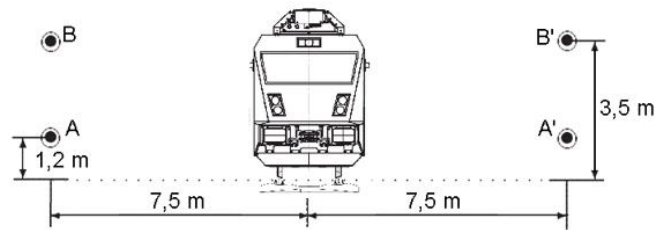


Fig. 1. Standard microphone positions for pass-by noise measurements according to EN ISO 3095:2025

Measured equivalent sound pressure levels were corrected to the reference speed of 80 km/h in accordance with EN ISO 3095:2025, allowing direct comparison of different vehicle types. The investigated rolling stock included contemporary electric multiple units (Stadler KISS and Stadler FLIRT), freight trains equipped with both composite and cast iron brake blocks, an older series 441 electric locomotive, a Siemens Vectron locomotive, and the diesel inspection vehicle subjected to type approval testing.

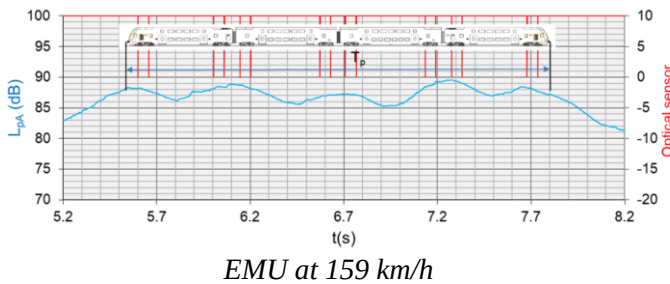
3. RESULTS AND DISCUSSION

The measurement campaign included six pass-by tests of contemporary electric multiple units, three freight trains with different braking technologies, one Siemens Vectron electric locomotive, and the diesel track inspection vehicle undergoing type approval testing.

3.1 Passenger trains

Figure 2 presents the sound pressure level recorded during the passage of a Stadler KISS electric multiple unit at a speed of approximately 159 km/h. The characteristic variation of the sound pressure level clearly indicates the passage of individual bogies, while the optical sensor pulses enable accurate determination of the measuring interval used for calculating the equivalent pass-by noise level.

Table 1 summarizes the pass-by noise results obtained for the tested electric multiple units. After correction to the reference speed of 80 km/h, all measured values satisfy the limit specified by EN ISO 3095:2025. The corrected equivalent sound pressure levels ranged between 74 dB and 80 dB, confirming the excellent acoustic performance of contemporary passenger rolling stock operating on Serbian Railways.



EMU at 159 km/h

Tab. 1. Pass-by noise results for EMUs

Test No	EMU series	V _{test} [km/h]	L _{pAeq,Tp} (v _{test}) [dB]	L _{pAeq,Tp} (80 km/h) [dB]	Limit Value [dB]
1	Stadler Kiss	146.6	82.00	75	80
2	Stadler Kiss	142.3	86.16	78	
3	Stadler Kiss	146.7	87.48	79	
4	Stadler Flirt	159.3	83.69	74	
5	Stadler Flirt	158.9	87.15	79	
6	Stadler Flirt	159.4	87.78	80	

The relatively small variation between repeated measurements demonstrates the good repeatability of the test procedure and indicates stable operating conditions during the measurement campaign. The results further confirm that modern vehicle design, improved suspension systems and disc braking technology contribute significantly to the reduction of rolling noise.

3.2 Freight trains and locomotives

Unlike passenger vehicles, freight trains exhibited considerably larger differences in pass-by noise depending on braking technology.

Figure 3 shows the sound pressure level recorded during the passage of a freight train consisting of a Class 441 electric locomotive and Sggn container wagons equipped with composite K brake blocks.

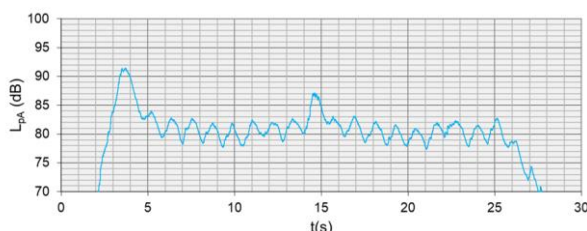


Fig. 3. Pass-by sound pressure level of freight train with composite brake blocks

In contrast, the freight train equipped with conventional cast iron brake blocks produced consistently high sound pressure levels along the entire train length, as illustrated in Figure 4.

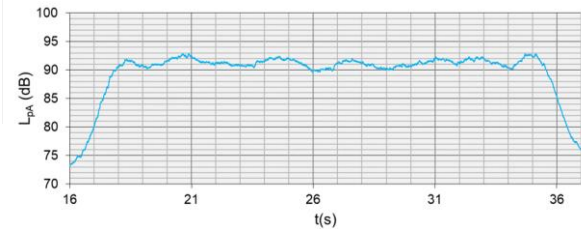


Fig. 4. Pass-by sound pressure level of freight train with cast iron brake blocks

The difference between the two braking technologies is clearly visible. While wagons equipped with composite brake blocks satisfy current European noise requirements, wagons fitted with cast iron brake blocks exceed the allowable limit by approximately 9 dB.

Table 2 summarizes the measured pass-by noise levels for freight trains, locomotives and the diesel inspection vehicle.

Tab. 2. Pass-by noise results for freight trains, locomotives and inspection vehicle

Train composition/ vehicle type	V _{test} [km/h]	L _{pAeq,Tp} (v _{test}) [dB]	L _{pAeq,Tp} (80 km/h) [dB]	Limit value [dB]
Loc. 441 + Sggn wagons with K brake blocks	81.0	82.32	82	83
Loc. 441 + different container transport wagons with K brake blocks	80.9	82.43	82	83
Loc. 441 + Eas wagons with cast iron brake blocks	77.7	91.31	92	83
Vectron locomotive	79.7	81.92	82	84
Diesel inspection car with disc brakes	80.3	81.66	81.6	
	80.8	80.91	80.8	
	81.1	83.20	83.0	
	158.4	87.42	78.5	
	156.2	87.47	78.8	
	161.1	88.21	79.1	
Average rounded to nearest decibel			80	85

The locomotive represents the dominant noise source, producing sound pressure levels close to 90 dB, whereas the container wagons generate substantially lower noise levels that remain within the prescribed limits for freight rolling stock.

The measurements also demonstrate the influence of locomotive design. The Siemens Vectron locomotive achieved a corrected pass-by noise level of approximately 82 dB, remaining well below the applicable limit. In comparison, the older Class 441

locomotive produced substantially higher sound pressure levels, primarily due to older traction equipment and conventional tread braking.

The diesel inspection vehicle fulfilled all requirements prescribed for type approval testing. The average corrected equivalent sound pressure level remained below the applicable limit value, confirming compliance with current European interoperability requirements.

Overall, the obtained results clearly demonstrate that brake block technology represents one of the dominant factors influencing pass-by noise of freight trains. Replacing cast iron brake blocks with composite friction materials reduces rolling noise by approximately 9 dB under identical operating conditions. Considering the logarithmic nature of the decibel scale, this reduction represents a significant improvement in environmental acoustic performance and highlights the importance of fleet modernization for achieving compliance with contemporary railway noise regulations.

4. CONCLUSION

Pass-by noise measurements performed on the upgraded Belgrade–Novi Sad railway line enabled a direct comparison of the acoustic performance of contemporary and legacy railway vehicles under identical test conditions.

The results confirmed that modern passenger rolling stock equipped with disc brakes satisfies the pass-by noise limits prescribed by EN ISO 3095:2025 with a comfortable margin. Similarly, the Siemens Vectron locomotive and freight wagons equipped with composite brake blocks demonstrated significantly lower noise emissions than older vehicle designs.

The most pronounced difference was observed between freight wagons fitted with composite and cast iron brake blocks. Under comparable operating conditions, freight wagons equipped with cast iron brake blocks generated approximately 9 dB higher pass-by noise than wagons using composite brake blocks. Considering the logarithmic nature of the decibel scale, this represents a substantial reduction in environmental noise emission and confirms that braking technology remains one of the dominant factors influencing rolling noise.

The study also confirms the importance of standardized measurement procedures and controlled track characteristics for obtaining reliable and

comparable pass-by noise results. Compliance with the requirements for rail roughness and track decay rate ensures that the measured noise levels primarily reflect vehicle characteristics rather than infrastructure effects.

The presented results support the continued modernization of railway fleets through the replacement of conventional cast iron brake blocks with composite friction materials, contributing to compliance with current European interoperability requirements and to the reduction of environmental noise along railway corridors.

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