Noise Measurements on Various Railway Superstructure Constructions

Kristyna NEUBERGOVA[a]*, Lukas TYFA [b],
David VASICA [c], Libor LADYS [d]

[a] CTU in Prague, Faculty of Transportation Sciences, Department of Transporting Systems, Horska 3, Prague 2, neubergova@fd.cvut.cz)
[b] CTU in Prague, Faculty of Transportation Sciences, Department of Transporting Systems, Horska 3, Prague 2, tyfa@fd.cvut.cz)
[c] CTU in Prague, Faculty of Transportation Sciences, Department of Transporting Systems, Horska 3, Prague 2, xvasica@fd.cvut.cz)
[d] EKOLA group, spol. s r. o., Mistrovska 4, Prague 10, libor.ladys@ekolagroup.cz

Abstract

In the Czech Republic, railway noise is calculated according to the Czech national methodology during the project preparation of the modernisation and optimisation of the railway lines. This methodology, however, arose in the last century, and its use leads to significant overvaluation of the noise load in surrounding areas, in particular for upgraded and optimized railway tracks with modern construction and when using modern trains, mainly passenger traffic (disc brakes, multiple units).
The aim of the project is to determine the noise emission data, in view of the railway superstructure constructions and the rolling stock in use, alternatively to find out correction for noise reduction between the original and modernized lines, so that it was possible to define the conditions under which the noise emission values are valid. This will allow to use the Czech methodology, or foreign one, so that the results of a calculation will be as close as possible to actual conditions, which will lead to design the optimized noise reduction solutions.
The main focus of the project is therefore to determine the real noise emission values. To this end, the systematic measurement is done on the Czech railway network. Suitable sites with or without reconstruction are selected. There are realised repeated and synchronous measurements of the noise from the same train which passed through different places with various track superstructure types.
From the known parameters of a moving train, tracks and on the basis of sound pressure level values, or possibly frequency spectrum, the impact of the railway superstructure type on the railway noise will be defined.

Keywords: railway noise, noise measurement, sound pressure level, railway transport, superstructure construction

1. INTRODUCTION

The issue of transport noise is one of the current topics. Although the debate concerns mostly road traffic noise, railway transport has also been of certain interest to experts and public. When the noise monitoring based on the Directive 2002/49/ES was performed in 2007, whose purpose was to map the current level of transport related noise pollution, it was found that almost 90 million European citizens were exposed to road traffic noise exceeding 55 dB during the day. According to the WHO (World Health Organization), the noise level over 55 dB is highly disturbing and can cause various diseases. The number of citizens disturbed by railway noise is lower, the figure is approx. 10 million EU citizens exposed to the noise level exceeding 55 dB during the day, but it is not negligible percentage. Although the noise monitoring in the Czech Republic confirmed the fact that the perceived noise annoyance is from 95 % caused by road traffic, railway noise cannot be considered marginal.
The subject of this contribution is to summarize the results of noise measurements from railway transport, which had been performed in the past two years. The objective of these measurements was to gather and assess sound pressure level values depending on a railway superstructure. Within the project TAČR called “The Influence of Railway

* Corresponding author.

Infrastructure Measures on the Mitigation of Noise Generation and Transmission from Moving Trains" (2011 – 2013), noise measurements in selected areas were performed and their results are summarized in the Conclusion.

2. RAILWAY NOISE, ITS SOURCES AND TRANSMISSION

Sound is an integral part of human environment, by means of which a person gains an important share of information of the world around them. Sound is a progressive longitudinal mechanic vibration through elastic ambience, capable of being detected by hearing. Noise is then understood as any unwanted sound that disturbs or annoys us and has harmful impact on human health.
Noise in the environment is described in legislation by *equivalent sound pressure level* $L_{Aeq,T}$, which is always related to a specific time interval. This value is defined as stable sound pressure level, which has energy content equivalent to variable sound, and therefore presumably the same harmful effect. It is determined as average energy from the sound pressure levels A in a specific time interval, it is measured in decibels (dB) and its value is adjusted to frequency by means of a frequency weighing filter, which is used to reflect differences in human sensitivity to the noise spectrum.
Another noise descriptor, which is used mainly in places where the noise results from a series of identified noise events (discreet noise events, such as passage of individual vehicles in a specified area, overflying aircraft), is *sound exposure level* L_{AE} *(SEL)*. In this case, the measured sound pressure is assessed in a randomly long time interval and related to standardized period T = 1s. This allows comparisons of individual events with each other. If we know the sound exposure level values of individual events and their frequency, we can determine the equivalent sound pressure level based on the defined relation in a specific place and in a given time interval.
There are four basic types of acoustic energy generation within railway transport, namely track noise, radio devices operation for railway staff and public information, railway station traffic, especially at formation yards with speed regulation of uncoupling with track brakes, and finally the sound signalization.
The following text is focused on the first type only, and that means on track noise. It can be generally stated that the track noise of a moving train affects the environment with a complex of noises from different sources (see Fig. 1).

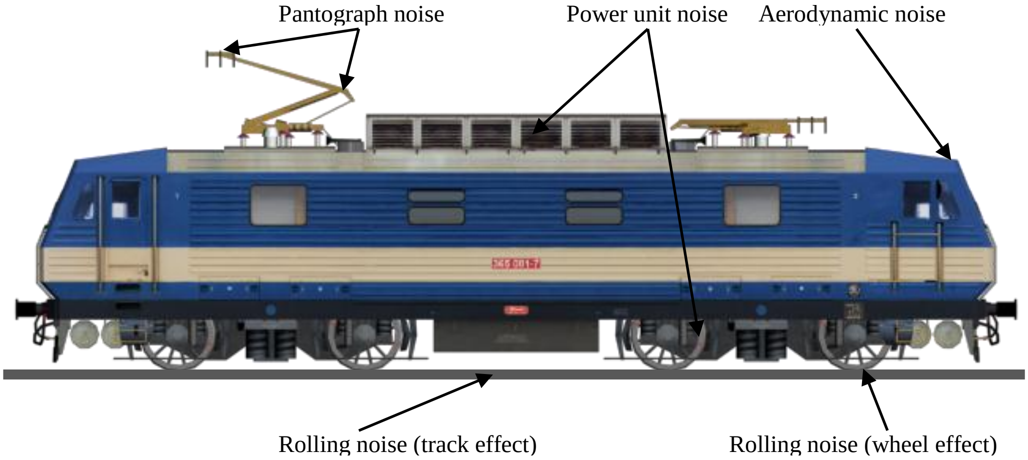

Fig. 1. Noise types [author]

The basic noise sources in railway transport are pantograph noise, aerodynamic noise, power unit noise and rolling noise. Pantograph noise in electric traction is generated in the height of approx. 5 meters. Aerodynamic noise, which increases with the train speed (for high speed trains, this noise type prevails over the others), generates from the flow of air and turbulence in the area of cars, their bogies and pantographs. This noise can be partly eliminated by using rail vehicles with better shape design. Power unit noise comes from a variety of sources including diesel and electric engines, gearings and fans. Rolling noise is caused predominantly by the wheel touchpad rolling on the rail. However, the noise is also generated in those areas of bogies, where the wheel set spinning causes friction.
The level of undesirable effects depends mainly on the routing type, traction type, construction, technical quality of superstructures and vehicles and on traffic speed and intensity. Noise transmission is dependent on climatic conditions, configurations and on the type of the surrounding ground surface.

3. RAILWAY NOISE MEASUREMENT

Before the measurement is initiated, its purpose needs to be analyzed and the objectives of the follow-up assessment need to be specified. First it is necessary to choose suitable sites and specific places for the measurement, and determine the methodology of measurements according to the legislation in force. Within the scope of the project, synchronous measurements in selected sites took place, so that the sound exposure from a single consist on different types of superstructures can be determined. Both sites after and before reconstruction have been selected.

The integral Sound Level Meters Norsonic, which were placed on every post in threes and in different heights and lengths (7.5 m away from the centre line of the track and in the heights of 1.2 m and 3.5 m above the top of the rail, and then 25 m away from the centre line and 3.5 m above the top of the rail), were used for the measurements.

As mentioned above, the measurements took place in two places of a selected track with different superstructure conditions (construction or deterioration, etc.) at the same time, so that the noise emissions from the same consists in both posts can be compared and the influence of the superstructure construction on the sound pressure level can be better determined.

For the assessment of railway noise, a method of comparing *sound exposure levels* L_{AE} during an individual train passing has been chosen. This descriptor is delineated in detail in the previous chapter.

The measurements themselves were performed in measuring campaigns, which consisted of eight steps. The first step was theoretical identification of track sections, followed by practical identification including a field survey. The third step was to select specific sites in a particular section. Next in order was the measurement term planning and in the fifth step its performance, considering the weather and traffic exceptions on the monitored track sections. In the following sixth step of the campaign, data were summarized and in the seventh step prepared for the follow-up assessment. In the last, eight phase, the data were statistically processed and expertly assessed.

(a) (b) (c) (d)

Fig. 2 – Measured construction types of rail fastening systems, (a) direct elastic system W14, (b) indirect elastic system KS, (c) indirect non-elastic system K, (d) indirect non-elastic system with divider heel baseplate [author]

4. MEASUREMENTS RESULTS AND THEIR ASSESSMENT

The following graphs illustrate componential results for passenger trains. The dependence of *sound exposure level* in dB(A) during an individual train passing on the train *speed* and *length*, determined by the number of axles, is compared. For illustrative and clarity reasons, a product of a speed figure and a number of axles is used. One dot in the graph symbolizes an individual train passing and there is a logarithmic trend line inserted.

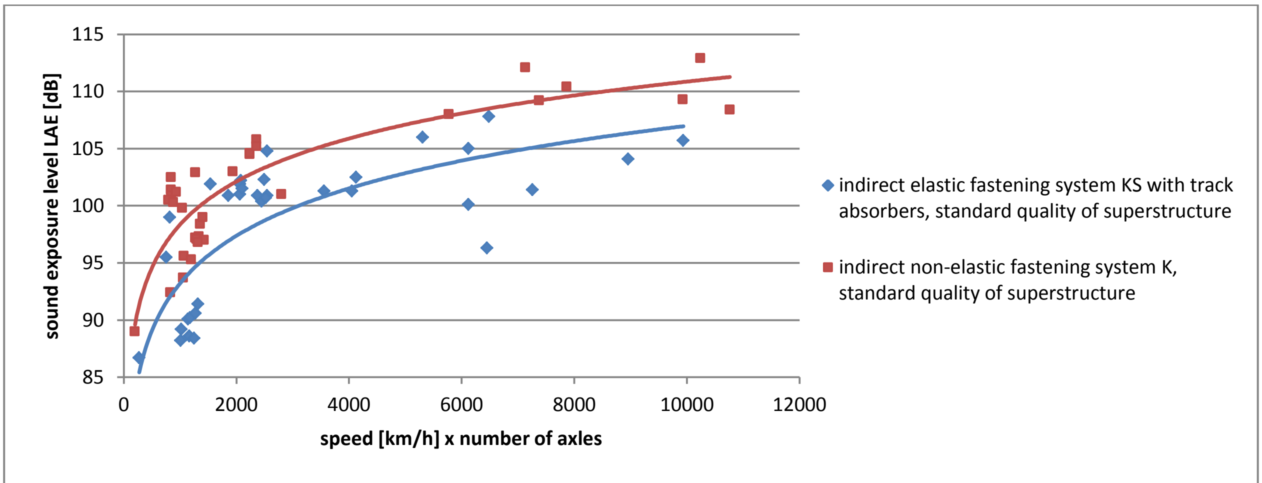

Fig. 3. Noise emissions – different fastening systems, electric traction [author]

All presented data come from sound level meters placed 7.5 m away from the centre line of the track and in the height of 1.2 m above the top of the rail.
The first graph (Fig. 3) shows the data from an electric traction, with indirect elastic rail fastening system KS with track absorbers and fastening system K. The average speed of measured trains was in both posts approximately equal, so the fastening system KS with track absorbers therefore shows lower noise level.
The following graph (Fig. 4) contains measurement data from an electric traction, too, and that with the fastening system K in standard quality and the same fastening system after reconstruction in 2009. The average train speed in the measuring post with fastening systems in standard quality was less than 10 km/h higher, no significant differences in the noise level were, however, confirmed.

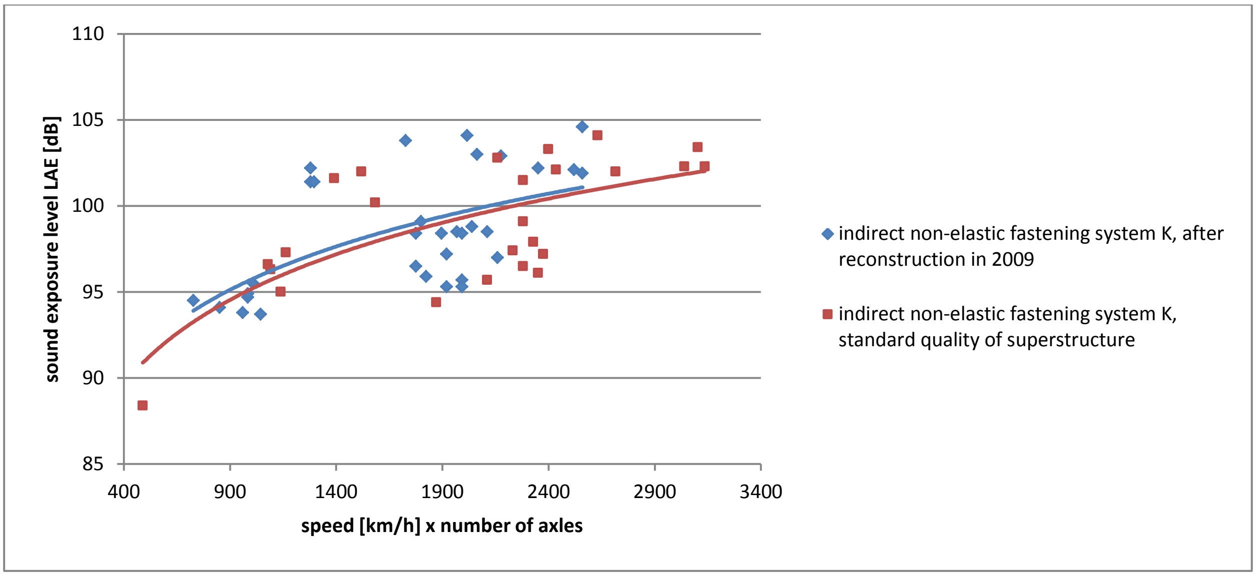

Fig. 4. Noise emissions – same fastening systems, different superstructure quality, electric traction [author]

Graph in Fig. 5 contains data from an electric traction, the indirect non-elastic fastening system with divider heel baseplate in average quality of superstructure and the direct elastic fastening system W14 with superstructure after modernization.

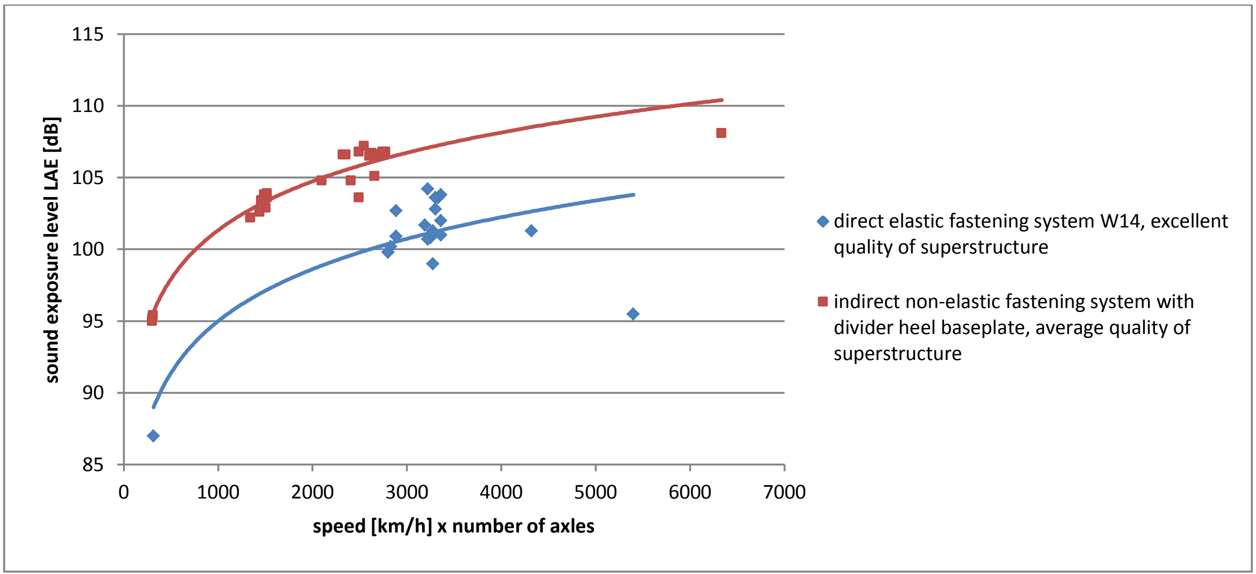

Fig. 5. Noise emissions – different fastening systems, electric traction [author]

Although the superstructure with the fastening system W14 is moved on with higher speed (more than 20 km/h higher on average), its noise emissions are significantly lower compared to indirect non-elastic fastening system. Graph in Fig. 6 contains measurement data from an electric traction, same fastening system W14 in excellent quality, but with noise barrier on one measuring site. The average train speed is nearly the same, nevertheless significant difference in noise level was recorded, as expected.

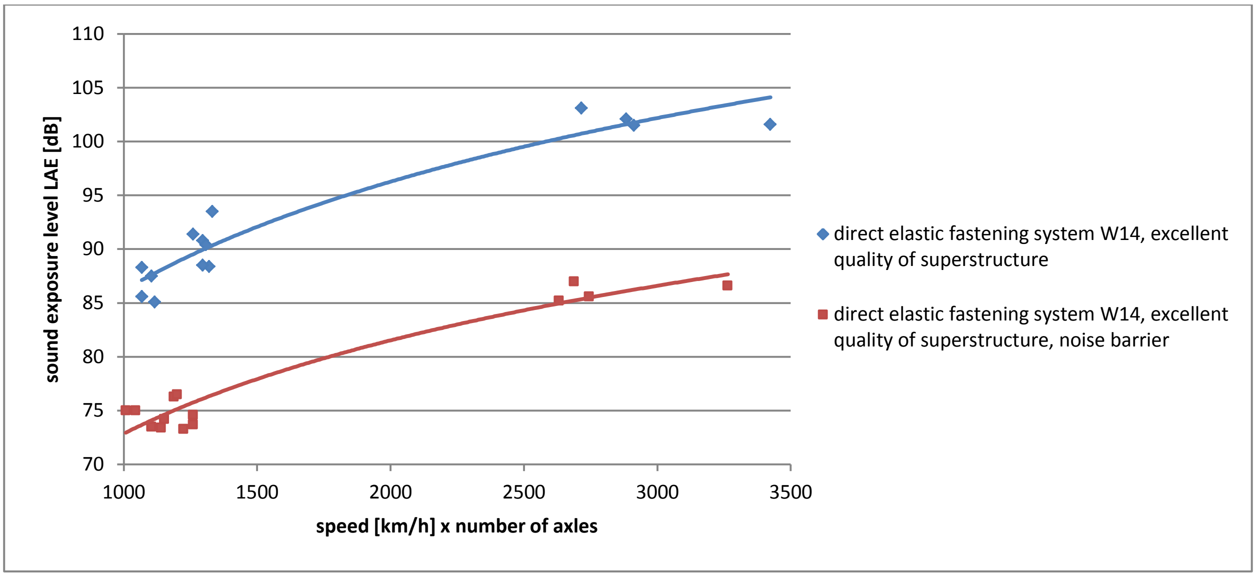

Fig. 6. Noise emissions from cars of different constructions on the superstructure with the fastening system K [author]

The assessment of measurements has also proved that noise emissions level is influenced not only by technical quality of the cars in consists, but also especially by their construction. Trains consisting of modern cars with disk brakes and the EMUs (electric multiple units) of a 471-071-971 series, show lower sound exposure level in comparison to standard cars with block brakes. Graph in Fig. 7 compares data measured in posts on the same superstructure construction (indirect non-elastic fastening system K), but with different car types. Trains with disk brakes are represented by the 471-071-971 class EMU.

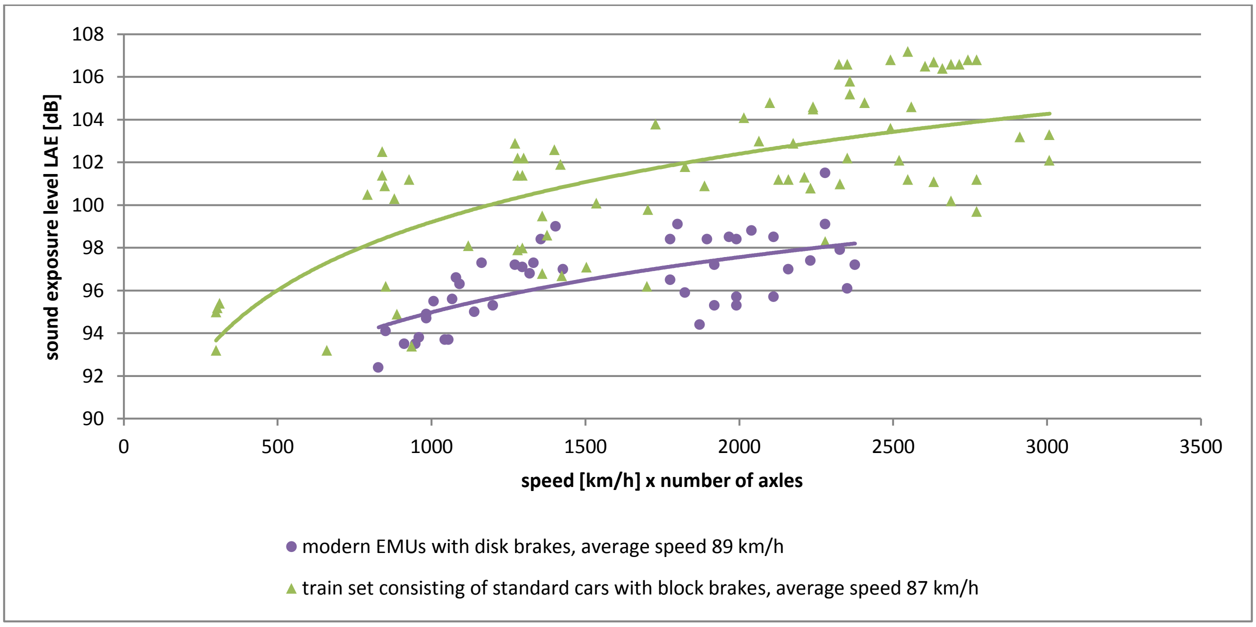

Fig. 7. Noise emissions from cars of different constructions on the superstructure with the fastening system K [author]

5. CONCLUSION

As it has been already mentioned in the second chapter, the basic noise sources in railway transport are traction noise (power unit noise), rolling noise (generated from the wheel rolling on the trail), and aerodynamic noise (air turbulences from a passing train). All these three main sources are associated with each other and cannot be unambiguously separated, each component is, however, dominant in a different extend of train speed. If there is a need to find dependence on different superstructure constructions, rolling noise, which dominates within the speed range of ca. 60 – 200 km/h, is essential. This fact needs to be considered when choosing measuring sites and processing the measured data. Rolling noise is further divided into wheel and track radiated noise. The above given parameters are also connected to each other and under standard operating conditions, when the measurements are performed, they cannot be separated from each other. There is a problem, though – track radiated noise is essential for finding dependence of noise emissions on different superstructure constructions; nevertheless, an element of "what moves on the track" has to be taken into account. Without the knowledge of this element, the problem of different superstructure construction cannot be solved efficiently. Measurements, which have been realized so far, confirm the given facts. It can be therefore concluded that the issue of railway noise has to be examined and solved systematically as a whole including all the influencing factors.

The aim of the project is to find out how different superstructure constructions influence noise generation and transmission from passing trains. This will result in unified methodology, which has not been present in the Czech Republic so far, and which allows definition of suitable corrections in calculation for the most commonly used methods for railway noise calculations with different track types.

In conclusion, the fight against traffic or railway noise in this case, is difficult and long-term process. Recent studies have shown that railway noise mitigation is a significant "by-product" of ongoing modernization and optimization of the railway lines in the Czech Republic.

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References

[1] NELSON, James. Wheel/Rail Noise Control Manual : Transit Cooperative Research Program Report 23 [online]. Washington. National Academy Press, 1997 [cit. 2011-08-18]. Available from WWW: <http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_23.pdf>. ISBN 0309060605.

[2] NEUBERGOVA, Kristyna; TYFA, Lukas; VASICA, David; LADYS, Libor. Influence of Various Track Forms upon Railway Noise. New Railway Trends – Transport – Telematics 01/2013. KPM CONSULT, 2013.ISSN 1210 – 3942.