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ADAPTATION OF RMR NOISE PROPAGATION PREDICTION METHOD FOR LATVIAN RAILWAY CONDITIONS

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Abstract. The problem of interim RMR (Reken en Meetvoorschrift Railkverkeerslawaai) methods adaptation for local railway conditions is analyzed. Cargo train noise levels were experimentally investigated on Latvian railway. The comparable analysis of measured and numerically calculated, using RMR method, cargo train noise levels in eight octave bands was performed. Comparable analysis results had shown that experimentally measured noise spectrum retains modeled spectrums shape, yet, having statistically constant level difference in all octave bands. The idea of RMR methods adaptation altering only one correction coefficient was proposed. More measurements are to be done to validate proposed approach.

Keywords: RMR, method, adaptation, noise, level, spectrum, octave band, railway

1. Introduction

During last few decades, with the growth of railway transport traffic, the overall railway noise level has increased rapidly. Therefore, the problem of acoustical ecology became more actual for railways.

In compliance with EC directive on environmental noise 2002/49/EC, in countries without their own national method for railway noise propagation prediction, RMR – the interim method for EU countries has to be used. Using this method strategic noise maps are to be built and strategic action plans are to be developed.

Balckars, Baranovskii, Ilina, Popov (2009) investigated the RMR methods applicability for Latvian railway conditions. It was found out that measured railway noise levels significantly exceed modeled noise level values using RMR method in all octave bands. That is because of the difference between Latvian and Dutch railway track and railway rolling stock vibration response functions. Thus, RMR method has to be adopted before application for Latvian railway conditions.

In RMR 2004 (2004) is described procedure for experimental RMR methods adaptation. Unfortunately, performance of described measurements is not technically possible for author. Yet, author assumes, that RMR methods adaptation can be done numerically without performance of complicated measurements.

This paper contains results of numerical approach for RMR methods adaptation for Latvian railway conditions.

2. RMR as interim method for EU countries

RMR was developed with particular reference to typical trains in the Netherlands, with the rolling noise element based on typical Netherland track without obvious defects on its running surface. Other Member States need to follow set procedures to categorise their trains into existing database (EC-WGAEN, 2006).

European Commission Working Group on Assessment to Noise Exposure in project report (2006) describes options by which relevant reference source terms for different trains can be obtained for input to RMR model.

Options 1–3 are based on the concepts of Procedure A referred to in RMVR 2004 (2004), where rolling noise is represented by a single noise level containing both the vehicle and track contributions to the overall noise level. Options 4–9 follow the concepts of Procedure B of that document, where the track and vehicle contributions are identified separately and allocated to source heights at the level of railhead and 0.5 m above the railhead respectively. All the options derive the total rolling noise as the starting point but, where separation of this total level into track and vehicle contributions is required, this is achieved by subtracting calculated vehicle or track contribution from the total.

Option 1: use the physical characteristics of the train (e.g. cast iron block brakes or disc brakes) to allocate it to an appropriate Dutch train category. This option has potentially the lowest level of accuracy, because it is dependent upon a judgment of the similarity between the trains in question with a defined Dutch category. It makes no correction for roughness and therefore implies that wheel and rail roughness levels are similar to those found in Netherlands.

Option 2: with a correction for the assumed typical roughness of the Member State's track. This option assumes that wheel roughness for bock or disc brakes in the Member State will be similar to than in the Netherlands.

Option 3: measurement of train pass-by noise, with acceptance of the track being typical of that found in Netherlands.

Option 4: option 3, but with a nominal apportionment of sound energy emission at two heights (at the railhead level and 0.5 m above).

Option 5: option 3, but with nominal default values combined effective wheel and rail roughness (effective because “contact filter” effects are included at the wheel/rail interface).

Option 6: option 3 but with combined effective roughness determined by indirect measurement techniques (e.g. PBA, Pass By Analysis software), and with nominal default transfer functions between combined roughness and, separately, vehicle and track sound energy contribution.

Option 7: option 3 but with wheel and/or rail roughness measured directly (using defaults where one of these is not available) and with contact filter effects accounted for. Also, with nominal default transfer functions between combined effective roughness and, separately, vehicle and track sound energy contribution.

Option 8: option 3 and the use of one, or more of the techniques PBA/VTN (Vibro-acoustic Track Noise software)/MISO (Multiple in Single Out software) or similar techniques to determine combined effective roughness and the transfer function between this roughness and, separately, vehicle and track sound energy contribution.

Option 9: option 3 with direct measurement of the roughness of the wheel and/or rail and the use of one or more of the techniques such as PBA to determine combined effective roughness (where it has only been possible to measure directly wheel or rail roughness but not both). Subsequently to use VTN/MISO to measure the transfer function between this roughness and, separately vehicle and track sound energy contribution.

This option, especially where both wheel and rail roughness can be measured directly, is likely to provide the highest precision in determining rolling noise source terms.

Unfortunately, during this and previous works author had possibility to use only first three options.

3. RMR modeled emission values per octave band

In RMR trains are divided into the following railway vehicles categories (these are primarily differentiated on the basis of drive unit and wheel brake system): brake-padded passenger trains (also electrical motor mail vehicle); disk-braked and brake-padded passenger trains; disk-braked passenger trains; brake-padded freight trains; brake-padded diesel trains; diesel trains with disk-brakes; disk – braked urban subway and rapid tram trains; disk-braked Inter City and slow trains; disk-braked and brake-padded high speed trains; high speed trains of the ICE-3(M) (HAST East) type.

Vehicles not mentioned here are allocated to the next appropriate category based on their drive unit, wheel brake system or maximum speed.

In this paper are used measurement results of cargo train noise levels. Cargo trains fit category number four in RMR description: all types of freight trains with cast-iron block brakes.

In RMR up to four different noise sources are considered. There are two different sources for train categories 1 to 8: at the level of the railhead and 0.5 m above railhead.

For the RMR the basis of the calculation is the sound power level per meter rail length for each source and each octave band between 63 Hz and 8 kHz as logarithmic function of train speed.

The A-weighted equivalent noise level in each octave band for train type category is the energetic summation of all noise sources in this octave band. For RMR train type category four the formula is:

$$L_{Aeq} = 10 * log\left(10^{\frac{L_{bs}}{10}} + 10^{\frac{L_{as}}{10}}\right) + L_{GU} - L_{OD} - \\ - L_{SW} - L_R - 58.6, \quad (1)$$

where L_{bs} – noise level from source at the height of railway track [dBA]; L_{as} – noise level from source at 0.5 m above railway track [dBA]; L_{GU} – attenuation due to distance [dB]; L_{OD} – attenuation due to propagation [dB]; L_{SW} – screening effect if present [dB]; L_R – attenuation due to reflections, if present [dB].

L_{bs} and L_{as} are energetic summations of braking and non-braking train noise for each noise source:

$$L_{bs} = 10 * log\left(10^{\frac{L_{bsnr}}{10}} + 10^{\frac{L_{bsr}}{10}}\right), \quad (2)$$

where L_{bsnr} – non-braking train noise at the height of railway track [dBA]; L_{bsr} – braking train noise at the height of railway track [dBA].

$$L_{as} = 10 * log\left(10^{\frac{L_{asnr}}{10}} + 10^{\frac{L_{asr}}{10}}\right), \quad (3)$$

where L_{asnr} – non-braking train noise at the height of 0.5 m above railway track [dBA]; L_{asr} – braking train noise at the height of 0.5 m above railway track [dBA].

In case of train type category four,

$$L_{bsnr} = L_{nr} = L_{bsr} = L_{br} = L_{nr} - 3 = L_r - 3,$$

where

$$L_r = a + b * \log\left(\frac{v}{v_0}\right) + 10 * \log\left(\frac{Q_c}{Q_0}\right) + C_{tr}, \quad (4)$$

where a and b – train type correction coefficients (table 1); Q_c – average number of passing (braking for L_r and non-braking for L_{nr}) trains [h^{-1}]; Q_0 – reference value (1 h^1); v – average train speed (braking for L_r and non-braking for L_{nr}) [km/h]; v_o – reference speed (1 km/h); C_{tr} – track type correction [dB].

In case of jointless (welded and grinded) track C_{tr} is equal to 0 in all octave bands.

Detailed description of L_{GU}, L_{OD}, L_{SW}, and L_R can be found in RMR 1996 (1996).

Table 1. Correction coefficients a and b for RMR train type category four in each octave band

	Octave band center frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
a	30	74	91	72	49	36	52	52
b	15	0	0	12	25	31	20	13

4. Measurement conditions

Measurements were done in compliance with the simplified method, described in RMR 2004 (2004).

4.1. Measurement equipment

The measurement equipment required is a sound level meter with octave spectrum analysis and a rail roughness measuring device (unless the site roughness is already known) according to the procedure described in EN ISO 3095, January 2001.

All equipment, including analysers, cables and microphones must satisfy the requirements for “type I” equipment according to EN 61260. Microphones must be calibrated with nearly flat frequency characteristic in the free field. The 1/3 octave filters and octave filters must satisfy EN 61260. The microphones must be equipped with a windshield. Before and after every measurement session, the microphone measurement chain is calibrated using calibrators with an accuracy of at least ±0.3 dB (class I according to HD 556 S1), at one or more frequencies in the relevant frequency domain. Measurement results must be rejected if there is a difference of more than 0.5 dB in the calibration. The frequency domain lies between 20 and 10 000 Hz. The calibrators must be checked at least once a year according to HD 556 S1. The instrumentation must be checked at least twice a year according to EN 61260.

4.2. Tracks

A test track is selected that is not only smooth, but also radiates as little noise as possible for a given roughness excitation (low response). Such a track may be specially built over a limited length of about 100 m.

The track type where measurements are carried out is specified as UIC 54 rails on mono block or duo block concrete sleepers with rail pads with static stiffness of 300–500 kN/mm at 60 kN preload (e.g. 4.5 mm cork rubber pads).

4.3. Vehicles

The vehicles selected for the test must satisfy the following. For unpowered vehicles, at least four vehicles are used in the test. For powered vehicles and units, at least two units are tested. If the vehicles are part of a train with other rolling stock, the effect of adjacent vehicles must be taken into account and avoided if possible. The vehicles must have run at least 1000 km under normal operating conditions, with the braking system in operation. Wheels must be free of damage such as flats. The vehicles should be empty and all doors and windows must be closed. Powered vehicles should have a characteristic traction load. Auxiliary equipment must be in operation during the measurements.

4.4. Acoustical environment

The measurement site must offer free field conditions. The soil must be free of obstacles and there must be no reflecting objects such as walls, building, slopes or bridges nearby. The track must be in a flat environment. There should not be any obstacles near the microphones that may distort the noise field, e.g. persons. The observer must not influence the noise measurement by his position. The soil between track and measurement microphone must be as far as possible free of strongly absorbing surfaces such as snow, high grass, other tracks or strongly reflecting surfaces such as water. A ballast layer of 10 cm or more is allowed.

4.5. Meteorological conditions and background noise

Measurements must only be carried out at wind speeds below 5 m/s and without precipitation (rain, snow, etc.). The track must be dry and free of snow or ice. Temperature, humidity, air pressure, wind speed and wind direction should be registered during the measurements and stated in the report.

Background noise that might influence the measurements must be reduced to a minimum. The measured sound pressure level must be at least 10 dB above the background level in all octave and 1/3 octave bands.

4.6. Measurement position and quantities

The A-weighted equivalent sound pressure level in octave bands is measured at one cross-section, at 7.5 m from the track center line and 1.2 m above the rail surface level.

The train speed is measured and must be within 5 lm/h of the nominal speed for speeds below 100 km/h and 10 km/h for speeds above 100 km/h.

5. Carried measurements

5.1. Measurement equipment

For purposes of experimental investigation of railway rolling stock noise levels spectral distribution the spectrum analyzer SVAN 947, serial number 6862 with microphone SV22, serial number 4012051 and acoustical calibrator SV30A, serial number 10593 was used. All equipment satisfies above requirements.

5.2. Track, vehicles and acoustical environment

It is obvious that within the bounds of a small project it is impossible to specially build a test track and even to get all needed test vehicles. The only possibility is to look for places which fulfill requirements as good as possible and make as many measurements as possible.

Measurements were carried out at station "Nicgale", measurement place is shown in Fig 1.

Fig. 1. Measurement place near station "Nicgale"

Acoustical environment satisfied above requirements.

5.3. Meteorological conditions and background noise

During all measurement sessions the wind speed was below 5 m/s, there was no precipitation, the track was clean and dry.

The meteorological conditions were the following: air temperature 25˚C, relative air humidity 80 %, air pressure 751 mmHg.

The background noise level was measured periodically to confirm that it's level in all octave and 1/3 octave bands is at least 10 dB below the measured noise level.

5.4. Measurement position and quantities

The A-weighted equivalent sound pressure level in octave bands was measured at one cross-section, at 7,5 m from the track center line and 1,2 m above the rail surface level (Fig 2).

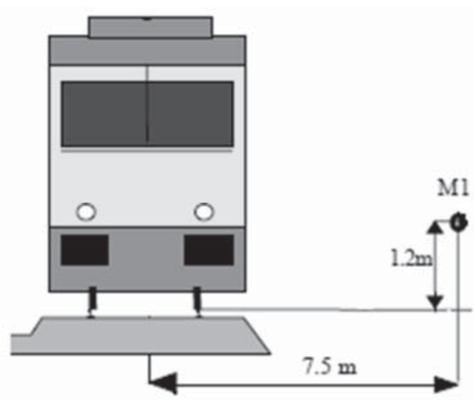

Fig. 2. Measurement equipment position

The train speed was read later from train speed registry cards.

6. Comparable analysis of measured and modeled train rolling noise values

Measurements were performed for different vehicle types, but all they correspond to RMR train type category four (cargo trains).

In table 2 are shown measured noise level values in octave bands for five trains consisting only from tanks (rows 1 to 5), 6-th row contains averaged over five measurements values, 7-th row are modeled using RMR method noise level values for averaged over five measurements passing train parameters v and Q (speed and number of passing trains per hour).

Table 2. Measured and modeled noise level values in octave bands

N	Octave band center frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
1	74.8	76.3	82.2	86.3	89.3	89.7	87.1	81.2
2	67.5	76.2	82.9	87.7	90.6	89.6	86.6	80.2
3	68.0	76.0	81.5	86.6	89.3	88.6	85.1	77.7
4	70.3	75.7	82.2	87.5	90.1	89.4	85.9	78.1
5	67.8	76.7	80.4	86.2	88.9	88.2	84.4	75.5
6	69.7	76.2	81.8	86.7	89.6	89.1	85.8	78.5
7	26.0	40.4	57.4	58.8	58.0	55.3	52.5	40.6

It can be seen from table 2 that there is no significant between all five measured rolling noise level values in all octave bands. Train speeds were the following: 52 km/h, 50 km/h, 50 km/h, 58 km/h, and 55 km/h for N 1-5 correspondingly.

The averaged measured and modeled noise level spectrums in octave bands are shown in figure 3.

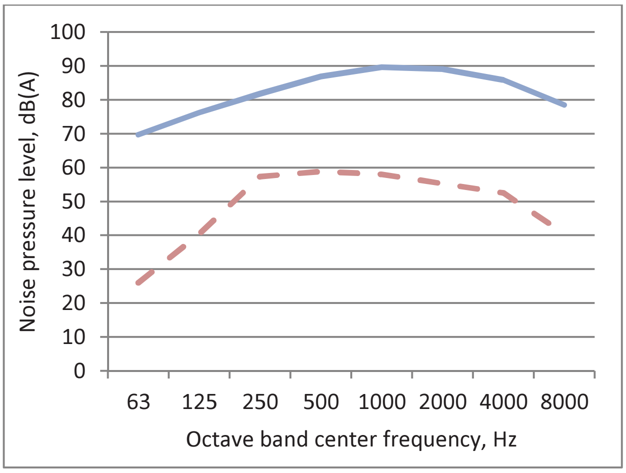

Fig. 3. Averaged measured and modeled noise level spectrums (solid line – measured, dashed – modeled)

It can be seen from figure 3 that the numerically calculated noise spectrum shape sufficiently precisely follows the shape of experimentally measured noise spectrum, except that the maximum levels for experimentally measured spectrums are in the octave frequency bands from 500 Hz to 2 kHz, but for the numerically calculated spectrums in the octave frequency bands from 250 Hz to 1 kHz, that is the whole numerically calculated spectrum is shifted down on the frequency scale in comparison to the measured spectrum.

It is needed to mention, that correction coefficient b values for RMR train type category four for octave bands with center frequencies of 125 Hz and 250 Hz are equal to 0, yet having relatively high correction coefficient a values. This results in certain speed independent noise levels at those octave bands.

Since there was no significant difference between measured noise level values in all octave bands for few different trains, it can be assumed that the difference between measured and modeled noise level values is statistically constant. If we also assume that railway track and vehicle wheel roughness at the measurement place had statistically average values as for entire country, the RMR model can be changed easily to fit measured noise level values, simply altering correction coefficient a by the difference between modeled and measured values. For described above situation the altered correction coefficient table would be the following.

Table 3. Altered RMR correction coefficient table

	Octave band center frequency, Hz							
	63	125	250	500	1k	2k	4k	8k
a	74	110	115	100	81	70	85	90
b	15	0	0	12	25	31	20	13

If the wheel and track roughness assumed to have reference value as for entire country, it is important for railway maintenance bodies guaranty that at other railway segments and for other trains roughness values will not exceed reference values.

In figure 4 are shown EN ISO 3095 and Netherland average rail roughness curves for train speed of 90 km/h.

It can be seen from figure 4 that even in Netherlands average rail roughness curve exceed ISO roughness limit curve at some wave lengths. Since ISO standard requirements are to be fulfilled also in Latvia, it can be assumed that average track roughness in Latvia is similar to one in Netherlands.

Rail roughness plays a big role in contribution to overall noise level only in case of jointless track. In case of track with joints or switches the contribution of impact noise will dominate and rail roughness can be neglected.

No doubt, that to validate such an approach, more measurements are to be done at different speeds and for different train and track types, but no specific equipment as for option 9 described above is required.

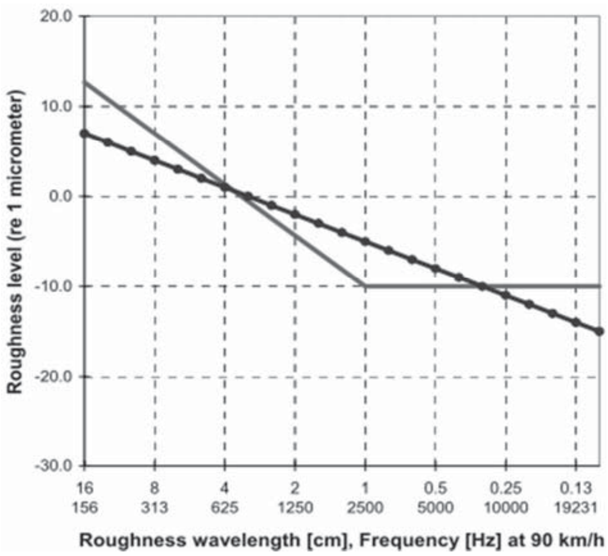

Fig. 4. ISO and Netherland average rail roughness

7. Conclusions

1. There is significant difference between measured on Latvian railway and modeled using RMR method train rolling noise values.
2. RMR has to be adopted before application on Latvian railway.
3. Modeled noise spectrum shape sufficiently precisely follows the shape of experimentally measured noise spectrum.
3. Altering only one RMR methods correction coefficient can be simple and quick way for building more correct strategic noise maps.
4. To validate the approach of altering only one correction coefficient more train rolling noise level measurements are to be done for different train and track types and for different speeds.

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