BNAM 2021
Baltic-Nordic Acoustics Meeting
3rd-5th of May, Oslo, Norway

Noise from 90-tonne vehicles, measurements and input to the prediction method

Henrik Naglitsch
Sweco Sverige AB, Vaksalagatan 10, Box 1733, 753 20, Uppsala, Sverige, henrik.naglitsch@sweco.se

Linda Grenvall
Sweco Sverige AB, Umestan Företagspark Hus 12, Box 110, 901 03, Umeå, Sverige, linda.grenvall@sweco.se

In Road traffic Noise – Nordic prediction Method [TemaNord 1996:525] the definition of heavy vehicles is "all vehicles with a mass exceeding 3,5 tonnes". In the Nordic countries the maximum weight of a road vehicle was 60 tonnes when the prediction method was developed. Today on some roads in Sweden vehicles of 90 tonnes are allowed. This becomes a problem when environmental impact assessments are being prepared as current prediction methods are not suited for these specific road traffic conditions. In this paper we present the results from measurements carried out on 90-tonne vehicles, loaded with iron ore and driving at speeds ranging from 30 to 80 km/h. The measured sound pressure levels have been compared to calculated levels from the Nordic prediction Method. The measured spectra, in one-third-octave bands, have also been compared to established spectra for traffic noise, C_{tr}, according to EN ISO 717-1:2013. The measurement results show that at speeds above 50 km/h the maximum and equivalent levels from the 90-tonne vehicles are significantly higher than those from "heavy vehicles" calculated in accordance with the Nordic prediction Method. At 30 and 40 km/h the measured maximum levels are lower than the calculated levels. The maximum sound level during acceleration of heavy vehicle from a start is higher than the maximum level from a pass-by at a steady speed of 40 km/h. Finally, the paper presents a method which allows for the adjustment of input parameters in the Nordic prediction Method to more accurately calculate sound levels according to the measurements.

1 Introduction

The mining company Kaunis Iron has an iron deposit located in Kaunisvaara about 25 km north of Pajala urban area. Ore transport take place using 90-tonne vehicles. As sound power data for such vehicles is missing in Road traffic Noise – Nordic prediction Method [TemaNord 1996:525] [1], measurements have been carried out to allow for more accurate calculations of noise emissions from ore transport on public roads.

2 Measurement method

The noise level measurements were carried out at Pajala Airport on 2014-06-10 and 2014-06-11 by Henrik Naglitsch and Linda Grenvall of Sweco Environment AB. The measurements have been conducted in accordance with Nordtest method NT ACOU 109 Vehicles: Determination of immission relevant noise emission [2]. The selection of microphone height and measurement of road temperature deviated from the Nordtest method, as described below. The sound level meter was placed in the middle of the runway so that the vehicles could reach and maintain their desired movement and engine near the measurement position. Selective speeds could be studied, and no account of other traffic needed to be taken, which would have been the case if the measurement had to be carried out on a busy road. Maximum sound level and Sound Exposure Level (SEL) were measured for 20 passages for each vehicle speed: 30, 40, 50, 60, 70 and 80 km/h.

The distance between the microphone and the centreline of the vehicle was 9.85 metres. The microphone height was 1.5 metres above ground level. According to the measurement method, two microphone positions should be used, we only used one. The length of the runway was 2300 m and longitudinal slope was 0.02%. Documentation on the runway surface coating type could not be obtained. Our assessment is that it was a high-quality asphalt coating with a moderate wear which can be translated into category 1a Asph. concr., dense, smooth (≤12-16 mm) according to NT ACOU 109. The distance between the vehicle route centreline and the sound measurement position was paved with asphalt. The road was dry although some remaining night moisture was present. The sound level measurements were made for a pass-by distance of 100 meters centred around the microphone position. The measurements were made in free-field conditions without any screening or reflective objects other than ground reflection. The microphone of SLM was positioned perpendicular to the pass-by centreline.

The vehicles used in the measurement were of make and model Scania R730 LB8x4 with engine that meets requirements in accordance with Euro 6. According to categorisation in NT ACOU 109, this corresponds to vehicle category 3d Very heavy trucks >6 axles. The vehicle would be loaded with ore with a total mass of 90 tonnes, but protocols from the weighbridge showed 81.1 tonnes. We decided to make a weight compensation of the readings according to the relationship:

$$\Delta L_m = 10\text{LOG}\left(\frac{90}{81{,}1}\right) = 0{,}45\ dB \quad (1)$$

This correction factor has been added to the measured values.

The driver accelerated up to an agreed speed and then kept constant speed past the entire measuring distance using the constant speed device. This driving pattern corresponds to driving condition 1 Cruising, Constant speed and gear according to NT ACOU 109. On day two, another truck was used for the last 11 measurements of take-off and stop. This car met the requirements of Euro 5. No significant difference in the noise level of the two cars could be observed.

3 Measurement results

3.1 Basic Maximum Noise levels $L_{AFmax,10m}$

The 5th percentile of normally distributed maximum sound pressure levels have been determined by Equation (2) based on the (arithmetic) average $L_{AFmax,avg}$ and the sample standard deviation s of the recorded maximum noise levels in accordance of *NT ACOU 039 Road Traffic: Measurement of noise immission – engineering method* [3]:

$$L_{\text{AFmax,5\%}} = L_{\text{AFmax,avg}} + 1.65\ \text{s} \quad (2)$$

where $L_{AFmax,avg}$ is calculated from all passages:

$$L_{\text{AFmax,avg}} = 10LOG\left(\frac{10^{L_{AFmax,1}/10} + 10^{L_{AFmax,2}/10} + \ldots + 10^{L_{AFmax,n}/10}}{n}\right) \quad (3)$$

and s is the standard deviation. $L_{AFmax,1}$, $L_{AFmax,1}$ etc. is the measured maximum pass-by levels for each passage.

$L_{AFmax,5\%}$ have been further modified to describe the sound pressure level 10 m from the middle of a road with infinite length according to Equation (4) from NT ACOU 109:

$$L_{\text{AFmax,10m}} = L_{\text{AFmax,5\%}} + 20LOG\left(\frac{\sqrt{(d-\frac{w}{2})^2 + {h_r}^2}}{10}\right) \quad (4)$$

where

d = measurement distance, in m

w = the axle width of the vehicle

h_r = height of the microphone

$L_{AFmax,10m}$ have been calculated for each speed, 30-80 km/h, and compared to calculated according to the Nordic Prediction Method, se graph below.

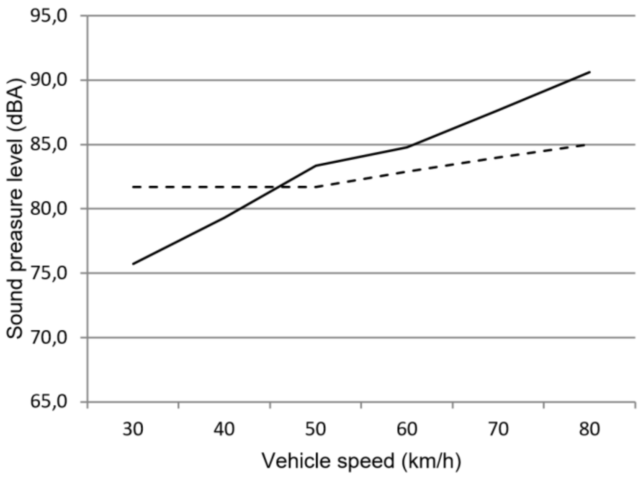

Figure 1 Basic Noise levels $L_{AFmax,10m}$, measured levels (continuous line) compared to predicted (dashed line)

It is obvious that the measured levels are higher than the predicted levels at speeds above 50km/h. It can be concluded that at speeds above 50km/h, the greater number of tyres of the 90-tonne vehicles than the number of tyres of conventional heavy vehicles, 38 tyres for Scania R730 LB8x4, combined with a higher load per tire, contributes to a higher noise emission due to rolling noise from the measured vehicles. It makes further sense that the difference in noise emission levels increases with higher speeds since noise from contact tyre/road surface increases with speed compared to noise from the engine.

3.2 Basic Equivalent Noise levels $L_{EAeq,T,10m}$

Sound Exposure Levels were measured and averaged logarithmical as:

$$L_{\mathrm{E}} = 10LOG(\frac{10^{L_{E,1}/10} + 10^{L_{E,2}/10} + \ldots + 10^{L_{E,n}/10}}{n}) \quad (5)$$

$L_{E,1}$ etc. is the measured SEL for each passage

L_E have been further modified to describe the sound pressure level 10 m from the middle of a road with infinite length according to formula in NT ACOU 109:

$$L_{\mathrm{E,10m}} = L_{\mathrm{E}} + 10LOG\left(\frac{\sqrt{\left(d-\frac{w}{2}\right)^2 + {h_r}^2}}{10}\right) - 10\log\left(\frac{\Delta\alpha}{2\arctan(5)}\right) \quad (6)$$

where

Δα = angle of circular sector covering the line of integration, in radians

To determine the equivalent level for 24 hours these formula from NT ACOU 039 have been used:

$$L_{\mathrm{Aeq,T,10m}} = 10LOG\frac{t_0}{T}\left(\sum_i n_i 10^{\frac{L_{E,10m}}{10}}\right) \quad (7)$$

where

T = reference time interval = 24 hours [s]

t_0 = reference duration (= 1 s)

n_i = number of vehicles passing for 24 hours [–].

$L_{EAeq,T,10m}$ have been calculated for each speed, 30-80 km/h, and compared to calculations according to the Nordic Prediction Method, see graph below

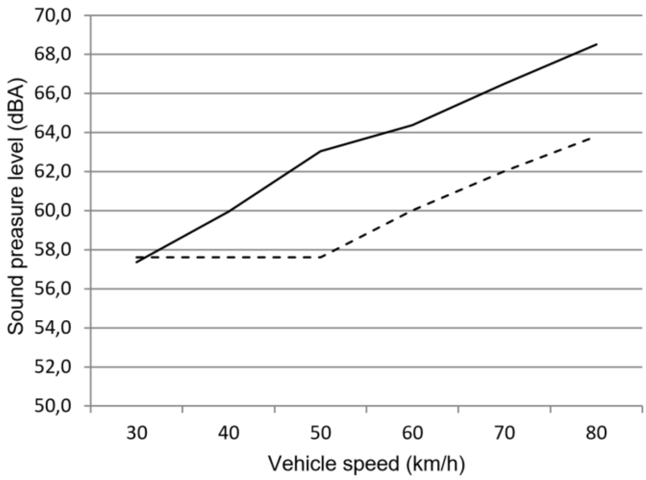

Figure 2 Basic Noise levels $L_{EAeq,T,10m}$, measured levels (continuous line) compared to predicted (dashed line)

The measured equivalent levels are higher than the calculated levels from the prediction method. This supports our conclusion that the greater load per wheel or axle results in higher noise emissions from 90-tonne vehicles when compared to conventional 60-tonne vehicles. The only exception is at 30 km/h when the measured level is approximately the same as the calculated level. It can also be observed that the relationship of equivalent levels with speed above 50km/h is the same for measurements and predictions.

3.3 Start up and acceleration

The results as presented above relate to noise from pass-byes at constant speed. We wanted to investigate if start/stop and accelerations/deceleration resulted in higher noise levels than pass-byes. The drivers were thereby instructed to drive at 60 km/h, brake and stop in front of the microphone, turn off the engine, turn on the engine, and accelerate to 60 km/h. They were told to drive as normal as possible and mimic the routines they would use in traffic whilst avoiding extra careful or extra ruthless driving manoeuvres. Maximum sound pressure levels over 16 cycles were measured and the results and the logarithmic mean values were calculated and compared to measured pass-by levels.

The maximum measured noise level from starting an engine was 83,3 dBA. Other actions, such as braking and acceleration, generated lower maximum levels. The conclusion is that starting an engine should be considered in calculations of maximum noise levels. The spectrum of the measured maximum sound levels from starting an engine was determined to be very similar to the ISO C_{tr} spectrum.

3.4 Measured spectrum

The Nordic Prediction Method does not take the spectrum of the sound into account but takes only into consideration a basic noise level in dBA. In many situations, for example when calculating the noise reduction of a façade, knowledge as to the sound spectrum is vital. The measured spectra for the maximum sound pressure levels are presented in *Figure 3*.

When calculating noise reduction of a façade we usually use spectrum ISO C_{tr} from European standard EN ISO 717-1 [4]. ISO C_{tr} describes “Urban road traffic”. A comparison between measured spectrum, and ISO C_{tr} has been made to investigate whether the C_{tr} spectrum can be reliably used to calculate the façade sound insulation when the noise sources are 90-tonne vehicles. ISO C describes “Highway road traffic at >80 km/h” and is excluded from the analysis because the maximum speed for the 90-tonnes vehicles is 80 km/h.

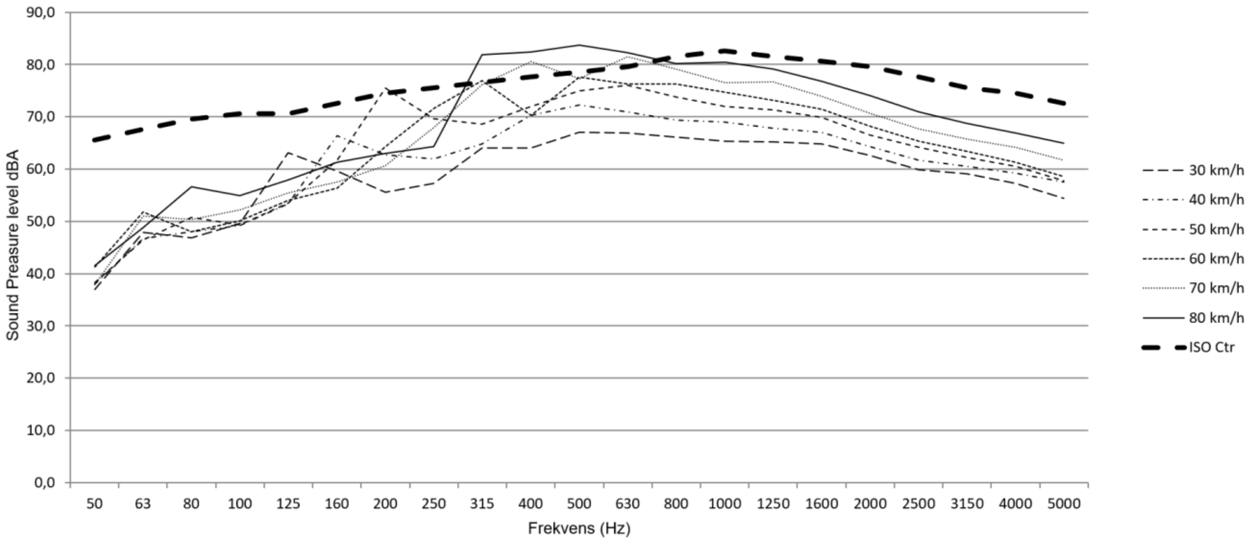

Figure 3 Measured spectra of sound pressure levels for maximum pass-by levels for each speed compared to ISO Ctr according to EN ISO 717 1

The level of the ISO C_{tr} is 90,6 dBA, the same as the dataset for 80 km/h.

As shown in Figure *3* the spectra of maximum pass-by levels from the 90-tonne vehicles do not contain more low frequencies noise when compared with ISO C_{tr}. In fact, the opposite is the case. At speeds of 30 km/h the spectrum is very close to the ISO C_{tr} and with increasing speed the proportion of lower frequencies noise decreases, as is to be expected. The spectra of equivalent noise levels are similar to the spectra of maximum pass-by levels.

It is interesting to note that the basic frequency of the engine shows an obvious peak at 125 Hz at 30 km/h. With increased speed the peak moves to a higher frequency and becomes less significant.

The conclusion is that the ISO C_{tr} spectrum can be used when calculating noise reduction of a façade even for noise sources such as 90-tonne vehicles.

4 Input to the prediction method

In this chapter we present input with regards to how to handle 90-tonne vehicles when calculating traffic noise levels using noise modelling software. By comparing the measured levels to the calculated levels from the prediction method we can state a speed dependent factor that can be added to the source data. Our suggestion is that the correction factor $dL_{surface}$ is used for this purpose. For maximum pass-by levels the factors are presented in Table 1 below:

Table 1: Speed dependent $dL_{surface,max}$ for maximum pass-by levels

Speed (km/h)	Measured L_{max} value (dBA)	Calculated L_{max} value (dBA)	$dL_{surface,max}$ (dB)
30	75,7	81,7	-6,0
40	79,3	81,7	-2,4
50	83,3	81,7	+1,6
60	84,8	82,9	+1,9
70	87,7	84,0	+3,7
80	90,6	85,0	+5,6
30	75,7	81,7	-6,0

The stated factors correspond to the calculated values of $L_{AFmax,5\%.}$

Because the factor is not the same for equivalent levels as for maximum levels, we must choose between two strategies. Either we apply two separate corrections $dL_{surface}$ for equivalent and maximum levels, or we apply the $dL_{surface}$ correction for maximum levels in conjunction with a correction to a traffic flow to determine the correct values for the equivalent level. The fictious traffic flow can be calculated from

$$\Delta_n = 10^{(dL_{surface,ekv} - dL_{surface,max})/10} \quad (8)$$

The proposed factors for equivalent levels are compilated in Table 2 below:

Table 2: Speed dependent $dL_{surface,eq}$ for equivalent pass-by levels

Speed (km/h)	Measured L_{eq} value (dBA)	Calculated L_{eq} value (dBA)	$dL_{surface,eq}$ (dB)	Δ_n (-)
30	57,4	57,6	-0,2	3,7
40	60,0	57,6	+2,4	3,0
50	63,0	57,6	+5,4	2,4
60	64,4	60,0	+4,4	1,8
70	66,5	62,0	+4,5	1,2
80	68,5	63,8	+4,7	0,8
30	57,4	57,6	-0,2	3,7

The real traffic flow is multiplicated by the factor Δ_n

There are two alternative ways to take maximum noise levels from start into account:

- Introduce a point source with sound power level 112 dBA, and ISO Ctr spectrum, at every point where it is likely that vehicles will start and stop, i.e. road intersections.
- Set the speed to a minimum of 50 km/h, regardless of the actual speed.

This is only necessary where the speed is 30 or 40 km/h, otherwise the pass-by levels at a constant speed will be dominant.

References

[1] Road traffic Noise – Nordic prediction Method, The Nordic Council of Ministers, Copenhagen [TemaNord 1996:525] *and also* Vägtrafikbuller, Nordisk beräkningsmodell, reviderad 1996, Samproduktion med Vägverket och Nordiska Ministerrådet, Naturvårdsverkets förlag, Rapport 4653.

[2] Nordtest method, NT ACOU 109, Approved 2001-11, VEHICLES: DETERMINATION OF IMMISSION RELEVANT NOISE EMISSION.

[3] Nordtest method, NT ACOU 039, Edition 2, Approved 2002-05, ROAD TRAFFIC: MEASUREMENT OF NOISE IMMISSION – ENGINEERING METHOD.

[4] EN ISO 717-1:2013, Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation (ISO 717-1:2013).