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

Noise spectra for railborne noise sources when calculating sound insulation of façade elements

Tore Fodnes Killengreen
Brekke & Strand Akustikk AS, Hovfaret 17B, NO-0275, Norway, tkn@brekkestrand.no

Sigmund Olafsen
Brekke & Strand Akustikk AS, Hovfaret 17B, NO-0275, Norway, so@brekkestrand.no

When calculating the airborne sound insulation of façade elements, a spectrum adaptation term is used to evaluate how different sound sources are transmitted through the façade elements. Based on measurements, spectra for noise sources can be defined. SINTEF Byggforsk Handbook 47 (HB47) define spectra for airports, road and rail. This paper will focus on rail. The rail spectra in HB47 originate from calculations with exception of the C_5 spectrum for metro. The paper evaluates whether the spectra given in H47 are valid for the train types MX3000, NSB BM 74/75 and NSB BM 71/73 that are commonly in use in the most densely populated areas in Norway. New spectra for use in calculations are proposed based on the comparison between the spectra in HB47, and the measured spectra for the train types MX3000, NSB BM 74/75 and NSB BM 71/73.

1 Introduction

SINTEF Byggforsk Handbook 47 (HB47) [1] defines the method for calculating indoor noise levels. When calculating indoor noise levels all façade elements are evaluated with spectrum adaptation terms as defined in ISO 717-1 [2]. From Mesihovic et al. [3] it is shown that the wrong spectrum adaptation term could cause ≥ 2 dB difference in calculated indoor noise levels for a given situation and façade elements. My own Master thesis [4] shows that the wrong spectrum could cause ≥ 4 dB difference depending on the situation. This inaccuracy when calculating indoor noise levels could either cause that the real indoor noise level are higher than the limit values as defined in NS 8175 [5], or lower than the limit values. Without relevant spectra for the actual noise source, there is no way to accurately predict whether the indoor noise levels comply with the limit levels. Based on recent measurements, see chapter 3, this paper aims to evaluate if the spectra given in HB47 are still valid for railborne noise sources used in Norway's most densely populated areas.

2 C-spectra given in SINTEF Handbook 47

HB47 was released in 1999, and of the 6 spectra for railborne traffic, 5 of them are calculated with Nord96 [6]. Only the C_5 spectrum for metro originate directly from measurements. The measurements are presumed to be of the old T1000 metro, which as of 2021 is out of service. The input to Nord96 is based on measurements done roughly 25-40 years ago. Even though Nord96 gives references to the reports documenting the measurements that define the input parameters, the reports are elusive. The C_2-C_5 spectra from HB47 is presented in Figure 1**.** The C_2 passenger train and C_4 high speed train have no clear connection to a specified train type.

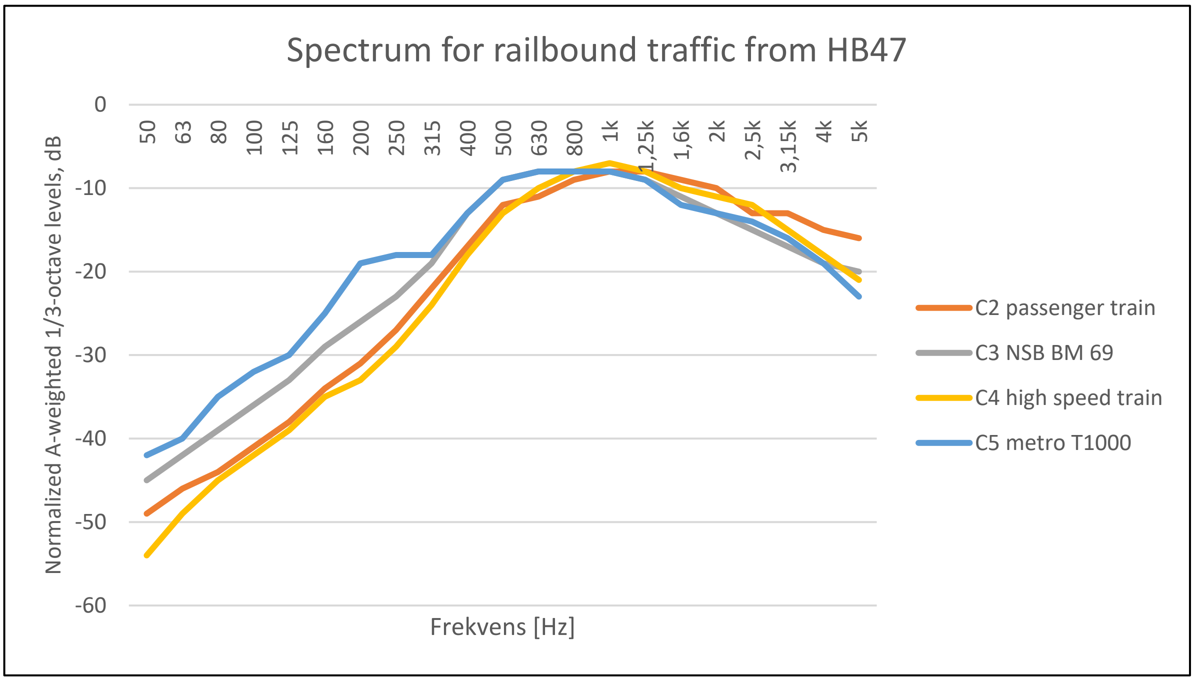

Figure 1: C spectra from HB47 for passenger trains and metro.

3 Spectra from recent measurements of noise from railbound traffic

Since the C spectra in HB47 where determined, now in 2021 new train types run the railways in Norway. In chapter 3.1 to 3.3 new spectra are presented for the train types commonly used in Norway's most densely populated areas.

3.1 Spectrum for the Oslo metro - MX3000

Sporveien AS has been working with Brekke & Strand Akustikk AS for several years with a yearly measurement program documenting noise from the Oslo metro for several different locations [9]. The spectrum presented in Figure 2 is an average of 4650 pass by measurements with speed between 20 km/h and 70 km/h done on the different locations and on trains with 3 or 6 cars. The spectrum for MX3000 is plotted with ± 1 standard deviation for speeds between 20 km/h and 70 km/h and in steps of 10 km/h. After evaluating the spectra for different speeds and measurement locations, it is decided that an average for all speeds and measurement locations, is an acceptable approximation for the MX3000 train type. For comparison, the C_5 spectrum from HB47 is also plotted. Below 200 Hz the C_5 spectrum deviates outside the standard deviation for the MX3000 spectrum. It is also worth noting that below 200 Hz, the standard deviation for the measured spectra for the MX3000 train type increases.

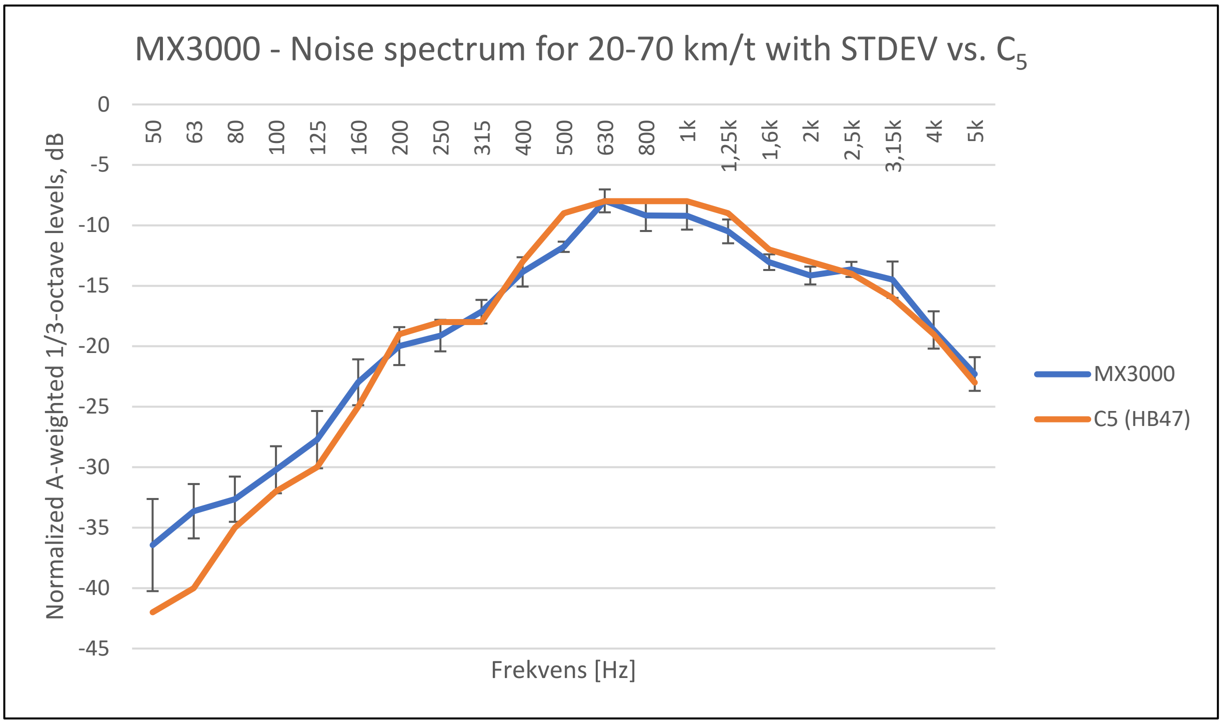

Figure 2: Normalized measured noise spectrum for the MX3000 train type compared to the C_5 spectrum from HB47.

Figure 3: A photo of the MX3000 train with 6 cars. Photo from Flickr.

3.2 Spectrum for NSB BM 74/75

In 2015 Brekke & Strand Akustikk AS measured the NSB BM 74/75 [7] train type to secure relevant a- and b-parameters for use in Nord96 calculations. The spectrum presented in Figure 4 is an average of 40 pass by measurements with speeds between 50 km/h and 210 km/h. The spectrum is plotted with ± 1 standard deviation for all measurements. After evaluating the spectra for different speeds and measurement locations, it is decided that an average of all available measurements is an acceptable approximation for the NSB BM 74/75 train type.

The C_3 spectrum for the train type NSB BM 69 is not shown because that train type is not relevant for this comparison. It is uncertain how the C_2 and C_4 spectrum in HB47 compare to the NSB BM 74/75 train type, and therefore both spectra are shown. Below 800 Hz the C_2 and C_4 spectrum deviates outside the standard deviation for the NSB BM 74/75 spectrum. It is also worth noting that below 315 Hz the standard deviation for the measured spectra for the NSB BM 74/75 train type increases.

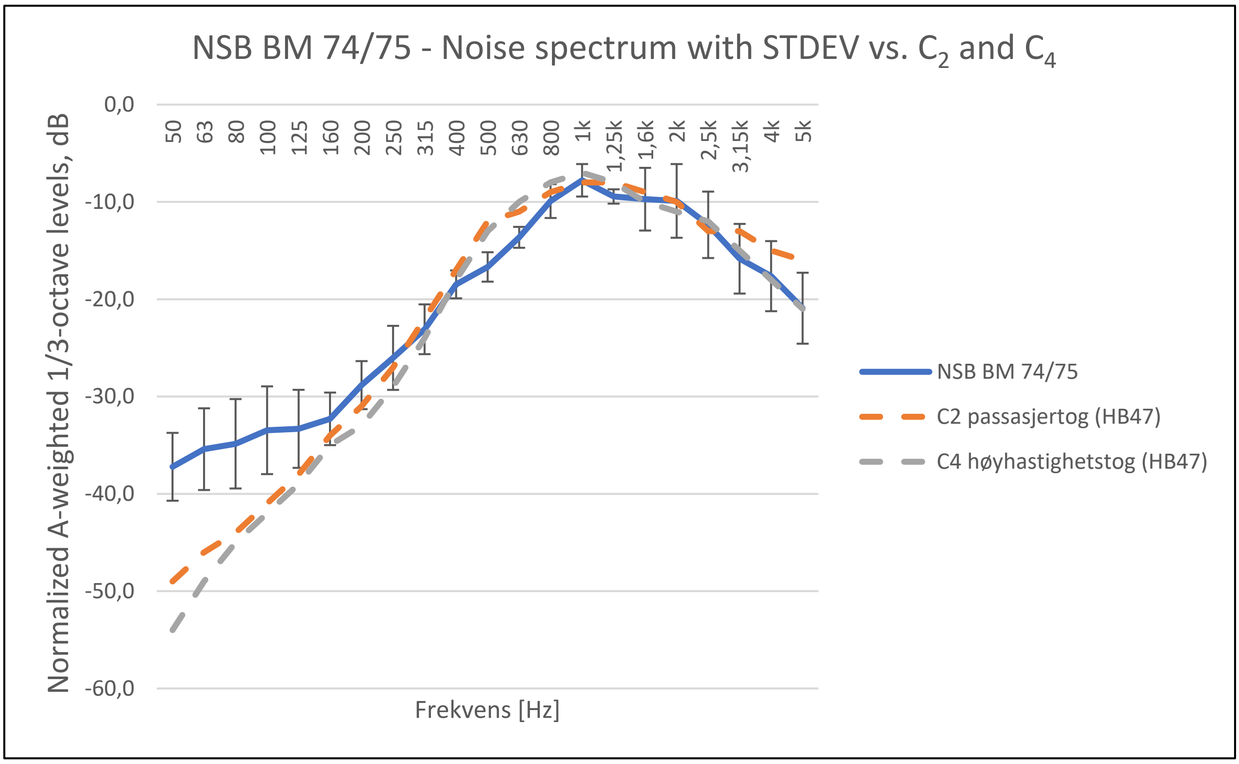

Figure 4: Normalized measured noise spectrum for the NSB BM 74/75 train type compared to the C_2 and C_4 spectrum from HB47.

Figure 5: A photo of the NSB BM 74 train. Photo from Wikipedia.

3.3 Spectrum for NSB BM 71/73

In 2015 Brekke & Strand Akustikk AS measured the NSB BM 71/73 train type to secure relevant a- and b-parameters for use in Nord96 calculations. The spectrum presented in Figure 6 is an average of 28 pass by measurements with speeds between 50 km/h and 220 km/h. The spectra is plotted with ± 1 standard deviation for all measurements. After evaluating the spectra for different speeds and measurement locations, it is decided that an average of all available measurements is an acceptable approximation for the NSB BM 71/73 train type.

The C_3 spectra for the train type NSB BM 69 is not shown because that train type is not relevant for this comparison. It is uncertain how the C_2 and C_4 spectra in HB47 compare to the NSB BM 71/73 train type, and therefore both spectra are shown. Below 800 Hz the C_2 and C_4 spectra deviates outside the standard deviation for the NSB BM 74/75 spectrum. It is also worth noting that between 315-800 Hz and below 200 Hz the standard deviation for the measured spectra for the NSB BM 71/73 train type increases.

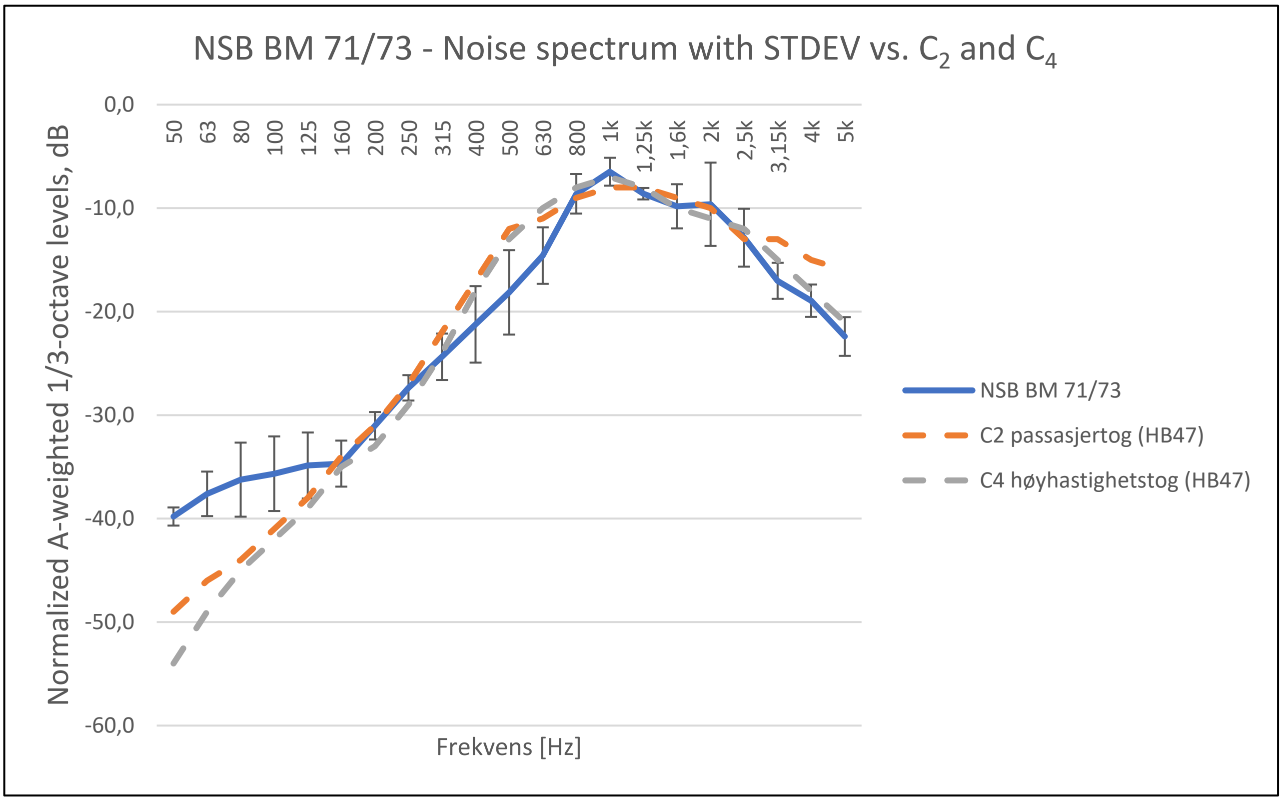

Figure 6: Normalized measured noise spectrum for the NSB BM 71/73 train type compared to the C_2 and C_4 spectra from HB47.

Figure 7: A photo of the NSB BM 73 train. Photo from Wikipedia.

3.4 Comparison of the spectrum for NSB BM 74/75 and NSB BM 71//73

Both the NSB BM74/75 and NSB BM 71/73 are in use between Trondheim, Oslo, Kristiansand, Stavanger and Bergen. The spectrum for both train types with their corresponding standard deviation and the average between them is presented in Figure 8. The spectrum for both train types are reasonably similar, and the standard deviation for both train types encompass the average between them.

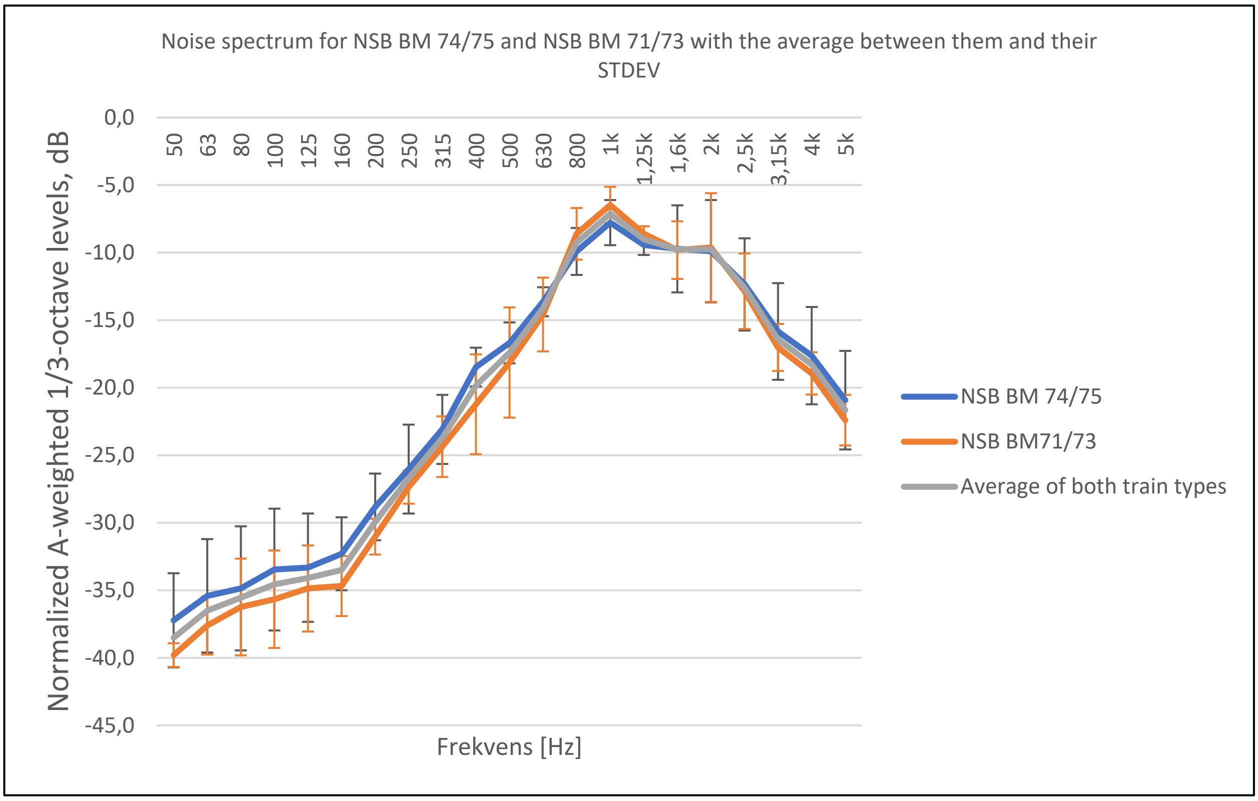

Figure 8: Noise spectrum measured on the NSB BM 74/73 and NSB BM 71/73 train types with the average of the measured spectra.

3.5 Data for the train types

Table.1 summarizes the normalized A-weighted 1/3-octave levels in dB.

Table.1: Normalized A-weighted 1/3-octave levels for the measured train types.

	Normalized A-weighted 1/3-octave levels, dB			
Frequency	MX3000	NSB BM74/75	NSB BM71/73	BM74/75 & 71/73
50 Hz	-36	-37	-40	-39
63 Hz	-34	-35	-38	-37
80 Hz	-33	-35	-36	-36
100 Hz	-30	-33	-36	-35
125 Hz	-28	-33	-35	-34
160 Hz	-23	-32	-35	-33
200 Hz	-20	-29	-31	-30
250 Hz	-19	-26	-27	-27
315 Hz	-17	-23	-24	-24
400 Hz	-14	-18	-21	-20
500 Hz	-12	-17	-18	-17
630 Hz	-8	-14	-15	-14
800 Hz	-9	-10	-9	-9
1 kHz	-9	-8	-6	-7
1,25 kHz	-10	-9	-9	-9
1,6 kHz	-13	-10	-10	-10
2 kHz	-14	-10	-10	-10
2,5 kHz	-14	-12	-13	-13
3,15 kHz	-14	-16	-17	-16
4 kHz	-19	-18	-19	-18
5 kHz	-22	-21	-22	-22

4 Discussion

Regarding the Oslo metro, the old T1000 train, the C_5 spectrum in HB47, and new MX3000 train types have a reasonably similar spectrum above 200 Hz. However, façade insulation is more critical at frequencies below 200 Hz and it is our recommendation that the spectrum measured on the MX3000 train type replace the C_5 spectrum in HB47 when calculating façade insulation.

The train types NSB BM 74/75 and NSB BM 71/73 have reasonably similar spectrum compared to the C_2 and C_4 spectrum from HB47 above 800 Hz. The NSB BM 74/75 and NSB BM 71/73 train types have similar spectra for frequencies between 50 Hz – 5kHz, and the standard deviation for both train types encompass the average between them. It is our recommendation that the averaged spectrum between the NSB BM 74/75 and NSB BM 71/73 train types replace the C_2 and C_4 spectrum in HB47 when calculating façade insulation. These two train types give rise to a significant portion of railway noise in Norway's most densely populated areas, and we consider the proposed spectrum more relevant in 2021 than the C_2 and C_4 spectrum in HB47.

The presented spectra for the MX3000, NSB BM 74/75 and NSB BM 71/73 all show increased uncertainty below 200 Hz – 300 Hz. Even though the proposed spectra in this paper reduce the uncertainty compared to the spectra given in HB47, there will always be variations in the measured spectrum that must be considered depending on situation.

References

[1] A. Homb, S. Hveem, *Isolering mot utendørs støy, beregningsmetode og datasamling. Håndbok 47*, Byggforsk 1999.

[2] Standard Norge, *ISO 717-1:1996. Acoustics - Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation*, Standard Norge, 2013

[3] Mesihovic et al. *The need for updated traffic noise spectra, used for calculation of sound insulation of windows and facades*, Internoise Hamburg, 2016.

[4] T. Killengreen, *Støyspektra fra veitrafikk – Gir glattede standardspektra et riktig bilde?*, NTNU 2006

[5] Standard Norge, *NS 8175:2012 Lydforhold i bygninger – Lydklasser for ulike bygningstyper*, Standard Norge, 2012

[6] Nordic Council of Ministers, *Railway Traffic Noise – Nordic Prediction Method*, The Nordic Council of Ministers, 1996

[7] L. R. Nordin, S. Olafsen, *ICP-34-A-10071_00A Fagrapport Togtype BM 74 og 75 Måling og beregning av inndata til støyberegninger*, Brekke & Strand Akustikk AS, 2015

[8] L. R. Nordin, S. Olafsen, *ICP-34-A-10072_00A Fagrapport Togtype BM 71 Måling og beregning av inndata til støyberegninger*, Brekke & Strand Akustikk AS, 2015

[9] S. Olafsen, A. Stensland, *Tram noise monitoring*, BNAM, 2018