DELIVERABLE D5.9

CONTRACT N°	**TIP4-CT-2005-516420**
PROJECT N°	**FP6-516420**
ACRONYM	**QCITY**
TITLE	**Quiet City Transport**
Subproject 5	**Design & implementation of solutions at validation sites**
Work Package 5.9	**Performance report of applied measures - Malmö**
	Part 2: In-field measurements of the influence of low barrier on railway noise

Written by

Jens Nielsen	**BAN**
Oskar Lundberg	**ACL**
Nicolas Renard	**BAN**

Date of issue of this report **2009-01-30**

PROJECT CO-ORDINATOR
PARTNERS

Acoustic Control	ACL	SE
Accon	ACC	DE
Akron	AKR	BE
Alfa Products & Technologies	APT	BE
Banverket	BAN	SE
Composite Damping Material	CDM	BE
Havenbedrijf Oostende	HOOS	BE
Frateur de Pourcq	FDP	BE
Goodyear	GOOD	LU
Head Acoustics	HAC	DE
Heijmans Infra	HEIJ	BE
Royal Institute of Technology	KTH	SE
Vlaamse Vervoersmaatschappij DE LIJN	LIJN	BE
Lucchini Sidermeccanica	LUC	IT
NCC Roads	NCC	SE
Stockholm Environmental & Health Administration	SEA	SE
Société des Transports Intercommunaux de Bruxelles	STIB	BE
Netherlands Organisation for Applied Scientific Research	TNO	NL
Trafikkontoret Göteborg	TRAF	SE
Tram SA	TRAM	GR
TT&E Consultants	TTE	GR
University of Cambridge	UCAM	UK
University of Thessaly	UTH	GR
Voestalpine Schienen	VAS	AT
Zbloc Norden	ZBN	SE
Union of European Railway Industries	UNIFE	BE

PROJECT START DATE **February 1, 2005**
DURATION **48 months**
Project funded by the European Community under the SIXTH FRAMEWORK PROGRAMME
PRIORITY 6
Sustainable development, global change & ecosystems

This deliverable has been quality checked and approved by QCITY Coordinator
Nils-Åke Nilsson

TABLE OF CONTENTS

0 EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

One of the targets of QCITY is to investigate different measures to reduce railway noise. The objective of the present study is to install a low barrier at 1.7 m from track centre and to measure the reduction in noise level from urban, InterCity and freight traffic.

0.2 STRATEGY USED AND/OR A DESCRIPTION OF THE METHODS (TECHNIQUES) USED WITH THE JUSTIFICATION THEREOF

The test track selected by Banverket (BAN) is a tangent track located between the stations Kungsängen and Bro (some 30 km northwest of Stockholm City) on the track between Stockholm and Västerås. The site contains a double track with a high density of passenger traffic (X12, X40, X60 and InterCity) and a lower density of freight traffic. The track superstructure (containing 60E1 900A rails, resilient rail pads and monobloc concrete sleepers on ballast) is according to the standard design currently used in Sweden.

0.3 BACKGROUND INFO AVAILABLE AND THE INNOVATIVE ELEMENTS WHICH WERE DEVELOPED

The low barrier used in the test (see Figure 0.3.1) was designed by one of the partners in QCITY, Zbloc Norden AB (ZBN). The nominal height of the barrier is 0.73 m above the top of the rail, but the barrier is lower at its ends. The inner face of the top section of the barrier is positioned 1.70 m from track centre. The section of the barrier that is facing the track is covered with an absorber made of rubber and plastic.

Figure 0.3.1. Zbloc low barrier and test track in Kungsängen – Bro

0.4 PROBLEMS ENCOUNTERED

Railway noise was measured at two adjacent track sections with and without noise barrier. One of the rails at the section with barrier had surface irregularities with wavelengths in the interval 10 – 16 cm. Apart from these, roughness level spectra for the track sections with or without low noise barrier were similar. The results from the noise measurements have been corrected in order to account for the difference in rail roughness.

Due to a speed restriction at the time of the test, train speed for all passing trains was limited to 70 km/h. The speed restriction was imposed because of construction work on the line.

0.5 PARTNERS INVOLVED AND THEIR CONTRIBUTION

Rail roughness was measured by Banverket using a Corrugation Analysis Trolley. Railway noise was measured at three sections (two sections with barrier and one section without barrier) at 7.5 and 10 m from track centre. The noise measurements were performed by Acoustic Control (ACL) according to the standard ISO 3095 and the Nordic Prediction Method for railway noise. All measurements were performed in October 2008.

0.6 CONCLUSIONS

In total, noise from 14 train passages (8 X60 trains, 2 X40, 1 X12, 2 InterCity and 1 freight) was recorded. The recorded trains passed the noise barrier with train speeds in the interval 64 – 73 km/h due to the imposed speed restriction.

The X60 trains generated TEL (Transit Exposure Level) spectra with a maximum in 1/3 octave bands with mid-frequency 630 and 800 Hz as generated by remaining grinding marks at wavelengths 2.5 – 3 cm. The freight, X12, X40 and InterCity trains showed a broader maximum in TEL spectra from 630 to 2500 Hz.

Without noise barrier, the X60 and X40 trains were the quietest among the trains measured, some 8 dB(A) quieter than the freight train. All 8 X60 train passages produced a very similar shape of the measured TEL spectrum.

The low noise barrier is found to be efficient in reducing TEL levels for the X60 and X12 trains. The reduction in total noise level is some 8 – 9 dB(A)-units. The barrier is less efficient, 4 – 6 dB(A), for the X40, InterCity and freight trains. The reason for this seems to be that the X60 and X12 have rail car sidewalls (bogies not included) somewhat enclosing noisy equipment underneath the rail car.

Rolling noise is generally concluded to be the dominating noise source for train speeds above 50 km/h. Thus, it is possible that the noise contribution from the "noisy" underfloor equipment may be negligible at 70 m/h. Nevertheless, the train type Alstom X40 carries a lot of noisy equipment on the roof and the insertion loss for this train was found to be lower than for X60. It is clear that noise from underfloor equipment should also be reduced by the low screens close to track, whereas the screen has no effect for

equipment installed on the roof. To clarify the influence of the underfloor equipment, it is desirable to repeat the test at higher train speeds.

Further, bogie skirts mounted on the train would enhance the acoustic performance of the low barrier even more.

1 TEST SITE

The test track superstructure contains 60E1 (UIC60) 900A rails, resilient rail pads and monobloc concrete sleepers on ballast, see Figure 1.1. The nominal sleeper distance is 0.65 m. The track design is the standard design currently used in Sweden.

The test track is a tangent track, and it is located between the stations Kungsängen and Bro (some 30 km northwest of Stockholm City) on the track between Stockholm and Västerås. The exact location is on track (in Swedish: bandel) 444, km 33+950. The site contains a double track with a high density of passenger traffic (X12, X40, X60 and InterCity) and a lower density of freight traffic.

Due to a speed restriction at the time of the test, train speed for all passing trains was limited to 70 km/h. The speed restriction was imposed because of construction work on the line.

Measurements of rail roughness were performed by Banverket. The railway noise measurements were performed by Acoustic Control. All measurements were performed in October 2008.

Table 1.1. Components of track system

Component	Type	Manufacturer
Rail	60E1 (UIC60) 900A	not known, 1996
Fastening system	P G1010	Pandrol
Rail pad	10 mm studded G10	Pandrol
Sleeper	Concrete monobloc	Strängbetong 1998

Figure 1.1. Zbloc low barrier and test track in Kungsängen – Bro

2 LOW BARRIER

A 50 m long low barrier from Zbloc Norden AB was installed in October 2008, see Figures 1.1 and 2.1. In simplified terms, the barrier assembly contains two parts: an upside-down, T-shaped bottom section and a 0.3 m wide rectangular top section. The nominal height of the barrier is 0.73 m above the top of the rail. However, the barrier is lower at its ends. The inner face of the top section is positioned 1.70 m from track centre, see Figure 2.2.

The section of the barrier that is facing the track is covered with an absorber made of rubber and plastic. Each barrier section is 3.5 m long and manufactured from concrete. An emergency door is placed at the centre of the barrier. The door is manufactured from steel and aluminium, and covered with the absorber.

Figure 2.1. Zbloc low barrier and test track in Kungsängen – Bro

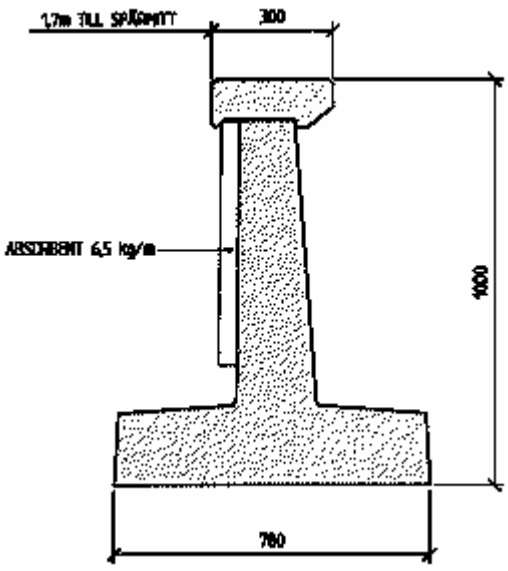


Figure 2.2. Cross-section of Zbloc low barrier

3 RAIL ROUGHNESS

Rail roughness was measured using the Corrugation Analysis Trolley (CAT). On both rails of the track, three lines with 10 mm lateral spacing (centred within the running band) were measured. The measurement data was recorded separately for one 50 m track section next to the noise barrier, and for one 50 m adjacent track section without noise barrier.

The track was ground in 2006. In most of the wavelength interval 0.5 – 32 cm, the roughness levels were below the ISO 3095 spectrum, with the exception of remaining grinding marks at around 2.5 cm. The right rail next to the low barrier had surface irregularities with wavelengths in the interval 10 – 16 cm. Apart from these, roughness level spectra for the track sections with or without noise barrier were similar.

The results from the noise measurements have been corrected in order to account for the differences in rail roughness, see Section 6.

Rail roughness level spectra from the two sections with and without barrier are shown in Figure 3.1. Results are presented in the form of roughness levels evaluated in 1/3 octave bands with centre wavelengths in the interval 0.5 – 31 cm. Roughness level L_r is defined as (with r_{ref} = 1 μm)

$$L_{\mathrm{r}} = 10 \cdot {}_{10}\log\left\{\frac{\tilde{r}^2}{r_{\mathrm{ref}}^2}\right\} \quad \text{[dB re 1 μm]} \tag{1}$$

Here $\tilde{r}$ is the root mean square value (evaluated in 1/3 octave bands) of the measured roughness profile. The displayed roughness level spectra were obtained by taking the average of the mean squares of the six measurement lines (three lines on each rail).

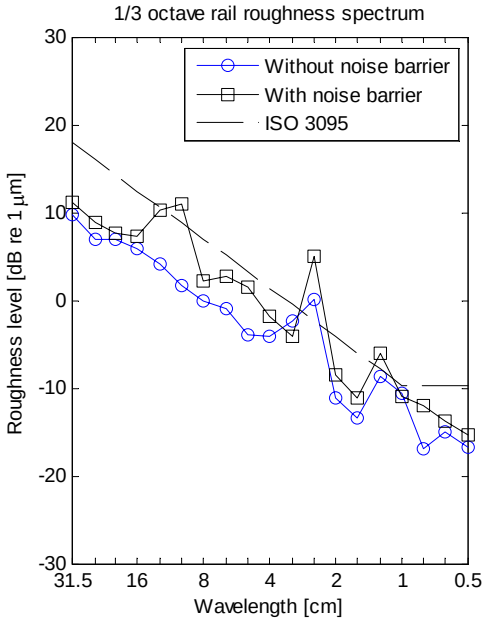


Figure 3.1. Rail roughness level spectra measured in Kungsängen – Bro

4 WHEEL BRAKES AND ROUGHNESS

The X12 passenger trains have both tread brakes with cast iron brake blocks and disc brakes. However, tread brakes are only mounted on the powered cars. Each train set contains one powered car and one trailer car. Thus, half of the wheels in a train set have both types of brake and half of the wheels have only disc brakes. The X12 passenger trains contain a maximum of four coupled train sets.

The X40 passenger trains have electro-dynamic brakes. The powered wheelsets are also equipped with tread brakes (scrubber brakes) where the brake blocks are manufactured from a composite material (JURID 865). The train sets with two cars have four powered wheelsets, and the train sets with three cars have six powered wheelsets.

The X60 passenger trains have no tread brakes.

Roughness levels for wheels passing the test site were not measured. Instead, wheel roughness levels are here assumed to agree with levels previously measured on wheels with similar brake systems, see Johansson [1] and Figure 4.1. The wheels were measured using equipment developed by the company Ødegaard & Danneskiold-Samsøe. Three probes in mechanical contact with the wheel tread measured the deviation from the mean radius. The measured wheels had travelled a distance of at least 100 000 km since the last turning/reprofiling. The roughness level spectra for the disc-braked X2 trailer wheels and tread braked (cast iron blocks) InterCity wheels are based on measurements of 5 and 6 wheels, respectively. The spectra for the two different types of freight bogies (G66 and Y25) with cast iron brake blocks are based on 14 and 22 wheels, respectively.

It is here assumed that the X40 and X60 passenger train wheels have wheel roughness similar to the X2 trailer wheels, whereas the X12 train wheels have wheel roughness similar to the InterCity wheels.

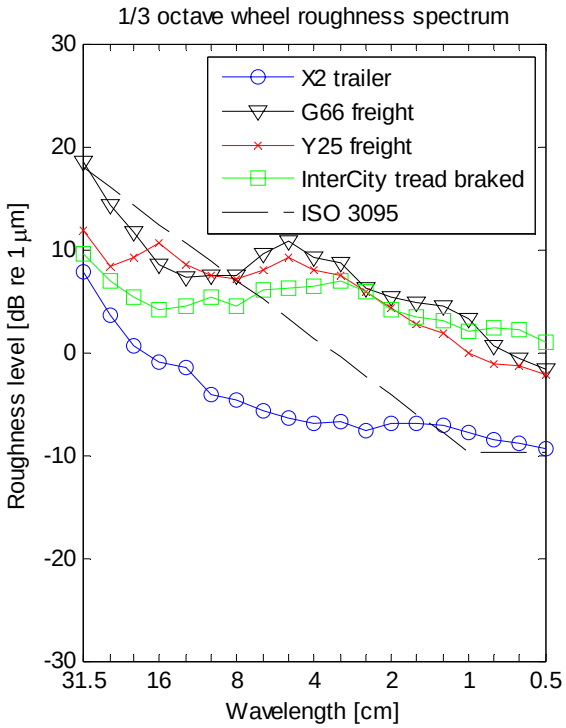


Figure 4.1. Wheel roughness level spectra based on results in Reference [1]

5 COMBINED WHEEL AND RAIL ROUGHNESS

The combined wheel and rail roughness for each combination of wheel type and track section is obtained as the energetic sum of roughness for each component. Thus, in each 1/3 octave band,

$$L_{\mathrm{r}}^{\mathrm{wheel+rail}} = 10 \cdot {}_{10}\log(10^{L_{\mathrm{r}}^{\mathrm{wheel}}/10} + 10^{L_{\mathrm{r}}^{\mathrm{rail}}/10}) \quad \text{[dB re 1 μm]} \tag{2}$$

Combined wheel–rail roughness level spectra are shown in Figure 5.1.

For freight and InterCity wheels, it is observed in Figure 5.1 that the combined wheel–rail roughness level spectra are similar for the two track sections with and without noise barrier except for wavelengths in the interval 10 – 12.5 cm. This corresponds to the frequency interval 150 – 200 Hz at 70 km/h.

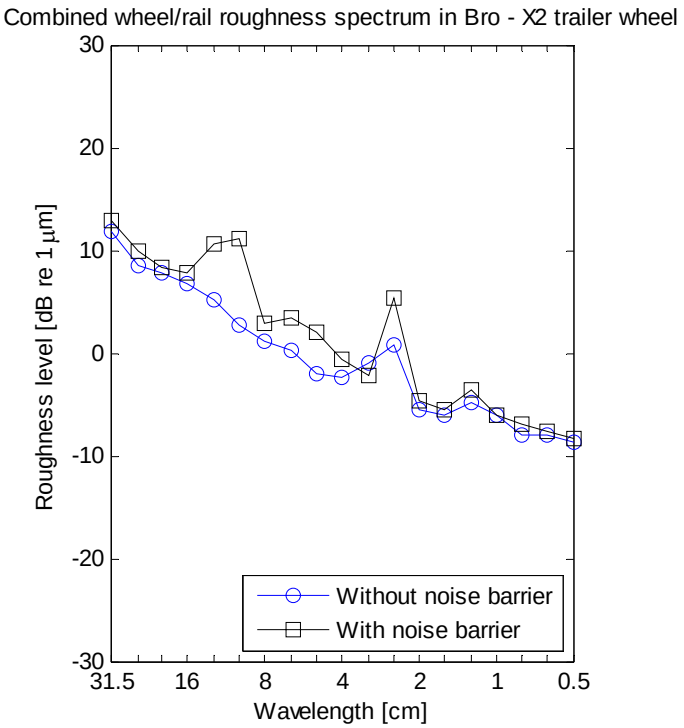


Figure 5.1a. Combined wheel–rail roughness level spectra: X2 trailer wheel with disc brakes

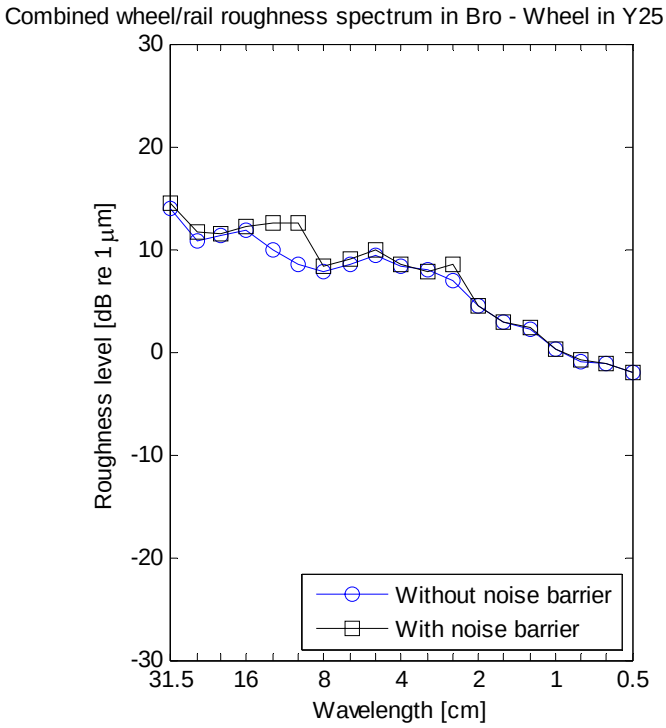


Figure 5.1b. Combined wheel–rail roughness level spectra: freight wheel in Y25 bogie with cast iron brake blocks

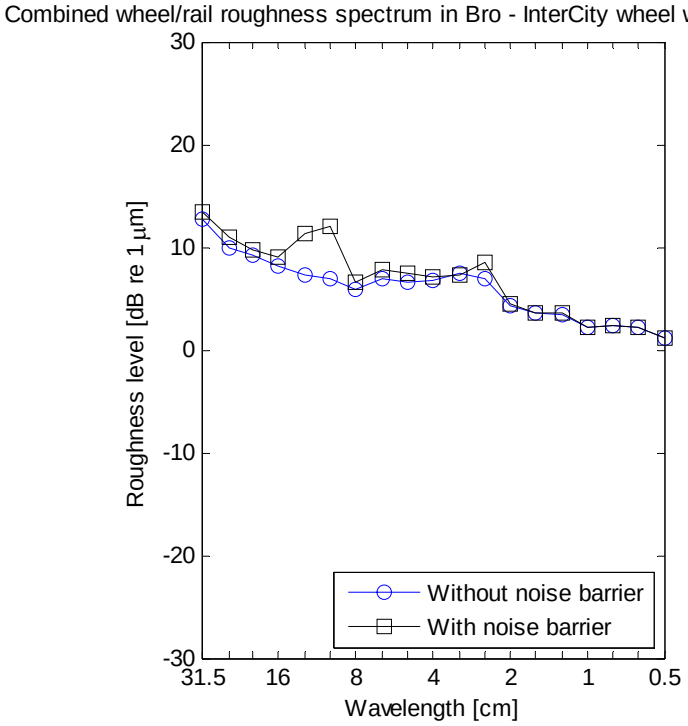


Figure 5.1c. Combined wheel–rail roughness level spectra: InterCity wheel with tread brakes (cast iron brake blocks)

6 ROUGHNESS CORRECTION

Measures have been taken in order to compensate for the differences in rail roughness between the track sections with or without noise barrier. The selected approach is to adjust the TELs measured at the track section without noise barrier so that they correspond to TELs that would have been measured if this track section had the same rail roughness as the track section with noise barrier. Note that this approach requires that it can be assumed that the wheel roughness levels discussed in Section 4 are representative for the wheel roughness levels present in the field test at Kungsängen – Bro.

For each 1/3 octave band, it is assumed that sound pressure $\tilde{p}_i$ is proportional to the combined wheel/rail roughness $\tilde{r}_i$ (i.e. the same assumption as in TWINS [2]).

$$\tilde{p}_i = \alpha_i \tilde{r}_i \tag{2}$$

where α_i is a transfer function containing the dynamic and acoustic properties of wheel, rail (and wheel–rail contact) at the current track section *i*. TEL spectra measured at the track section without noise barrier will be adjusted by relating the combined wheel/rail roughness $\tilde{r}_i$ at the current track section i with the combined wheel/rail roughness $\tilde{r}_{\mathrm{ref}}$ at the track section with noise barrier. Thus, a roughness corrected sound pressure $\tilde{p}_i^*$ may be obtained as

$$\tilde{p}_i^* = \alpha_i \tilde{r}_{\mathrm{ref}} = \alpha_i \tilde{r}_i \frac{\tilde{r}_{\mathrm{ref}}}{\tilde{r}_i} = \tilde{p}_i \frac{\tilde{r}_{\mathrm{ref}}}{\tilde{r}_i} \tag{3}$$

In logarithmic scale, this means

$$TEL_i^* = TEL_i + L_{\mathrm{r,ref}} - L_{\mathrm{r},i} = TEL_i + \Delta L_i \tag{4}$$

Note that different correction spectra ΔL_i are obtained for the track section without noise barrier depending on wheel type and train speed. The calculated correction spectra are shown in Figure 6.1.

Note that for traffic with tread brakes (cast iron), the required correction is moderate except at very low frequencies, see Figure 6.1b and 6.1c. This is because roughness levels on wheels with cast iron brake blocks are higher than the rail roughness on the relatively smooth rail sections present here.

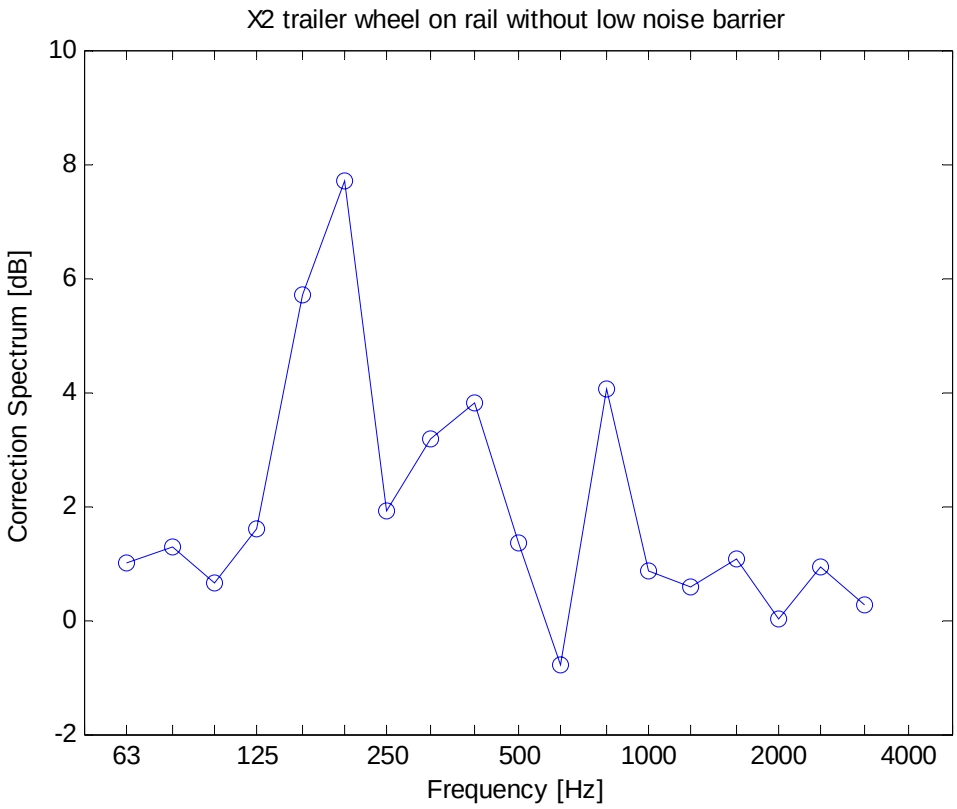


Figure 6.1a. Correction spectrum: X2 trailer wheel at 70 km/h

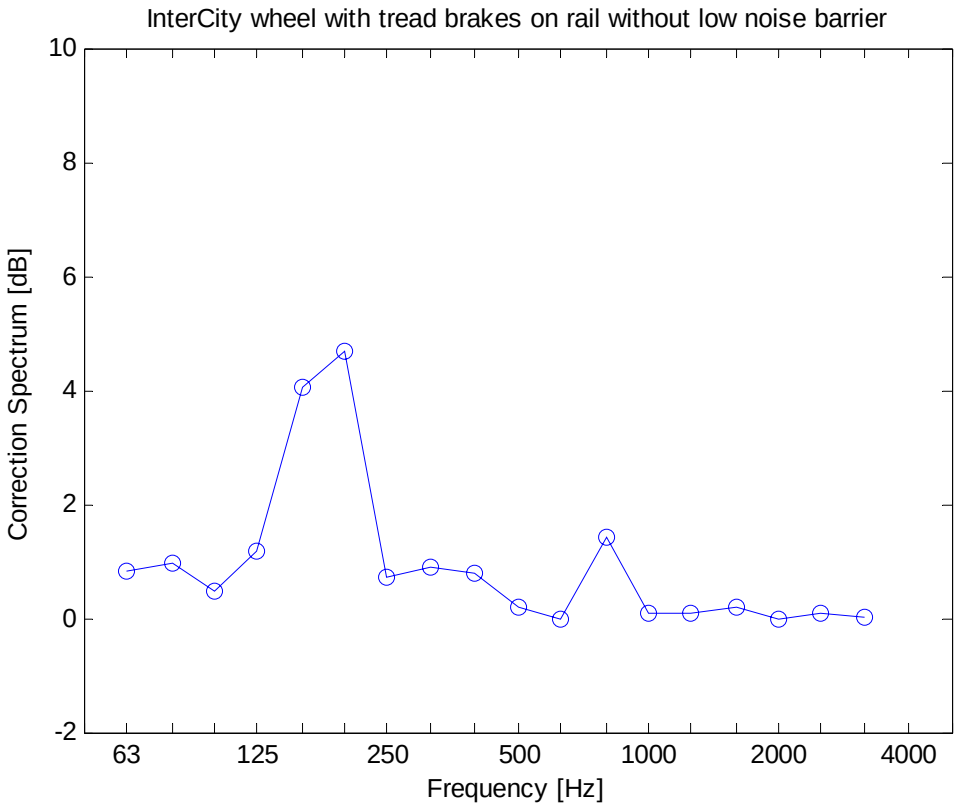


Figure 6.1b. Correction spectrum: InterCity wheel at 70 km/h

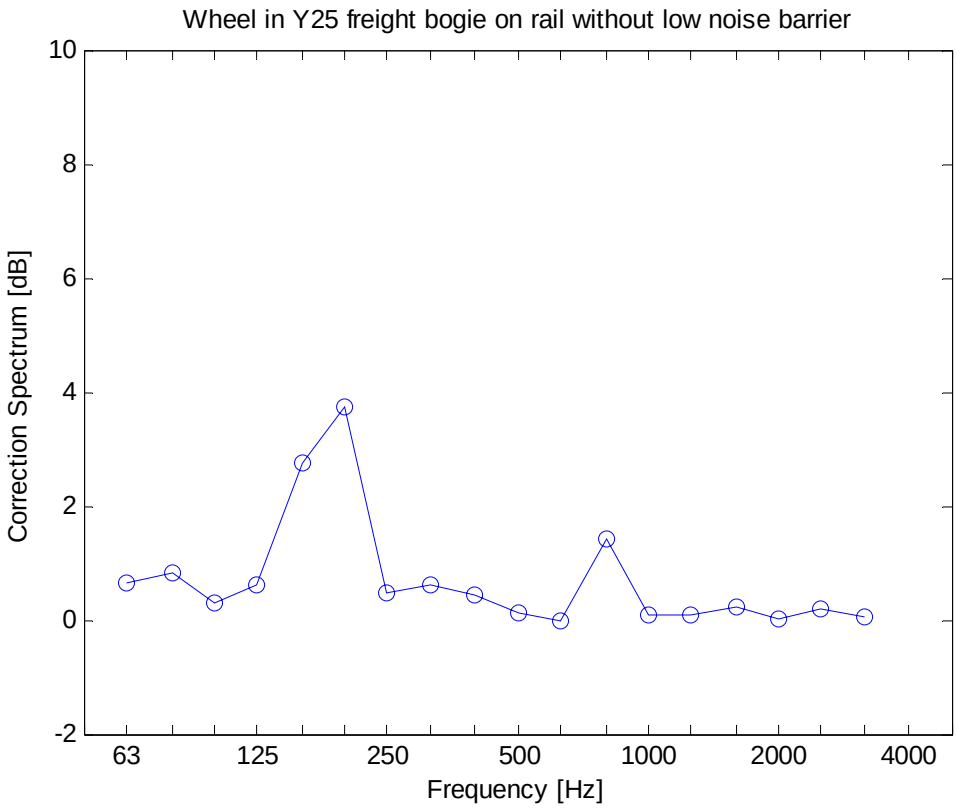


Figure 6.1c. Correction spectrum: freight wheel in Y25 bogie at 70 km/h

7 NOISE MEASUREMENTS

Railway noise was measured by Acoustic Control on 2008-10-28 between 10:00 and 15.00 for various types of traffic. The measurements were performed according to the standard ISO 3095 [3] and the Nordic Prediction Method for railway noise (assessment of source strength data) [4]. Microphones were positioned at 7.5 m from track centre (1.2 m above the top of the rail) and 10 m from track centre (2 m above ballast). The weather conditions (wind speed and wind direction, temperature and rain) were monitored during the measurements. Sound measurements were recorded for 14 train passages.

The measurements are presented as A-weighted TEL (Transit Exposure Level). TEL is defined as the equivalent sound pressure level *L*eq during a train passage normalised to the train passage time.

$$TEL = 10\log_{10}\left(\frac{1}{T_p}\int_0^T \frac{p_A^2(t)}{p_0^2}\mathrm{d}t\right) = L_{eq} + 10\log_{10}\left(\frac{T}{T_p}\right), \quad \text{[dB(A) re 20 µPa]} \tag{5}$$

where T is the measurement time interval [s], T_p is the pass-by time of the train [s], p_A is the A-weighted instantaneous sound pressure [Pa], p_0 = 20 µPa, and L_{eq} is the equivalent sound pressure level during the measurement time.

The train passage time and train speed were determined by two "light barrier" trigger systems according to Figure 7.1. When the light beam is broken by a train passage, the trigger system delivers a +5 V pulse.

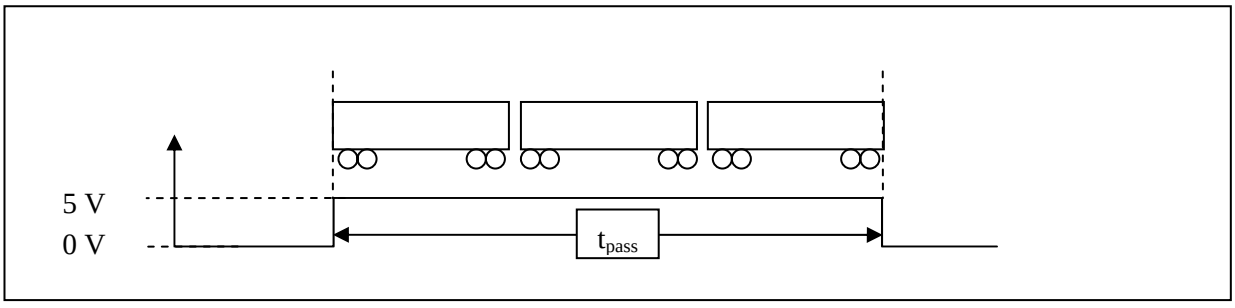


Figure 7.1. Trigger system for registering train passage time

7.1 MEASUREMENT EQUIPMENT

The used measurement equipment is summarized in *Table* 7.1.

Table 7.1. Equipment for noise measurements during train pass-by

Equipment	Type	Serial no.
Front-end	Brüel&Kjaer PULSE 12 channels	2519276
Microphones	Brüel&Kjaer 4189	2416653, 2516051, 2416654, 2416655, 2416656
Sound level calibrator	Larson Davis CAL200	0119
Weather station: wind speed, wind direction, temperature and rain	VAISALA Weather Transmitter WXT 510 with data logger MAWS 100	A2210003 and Z402095

7.2 MEASUREMENT POSITIONS

7.2.1 Measurement positions: sound

Sound measurements were performed in sections with low barrier and emergency door (microphones 1 & 2), with low barrier (microphone 3) and without low barrier (microphones 4 & 5) as presented in Figure 7.2. Microphones 1, 3 and 4 were positioned 7.5 m from track centre and 1.2 m above rail upper surface in accordance with the standard ISO 3095 [3]. Microphones 2 and 5 were positioned 10 m from track centre and 2 m above ballast in accordance with the Nordic prediction method for train noise (assessment of source strength data) [4].

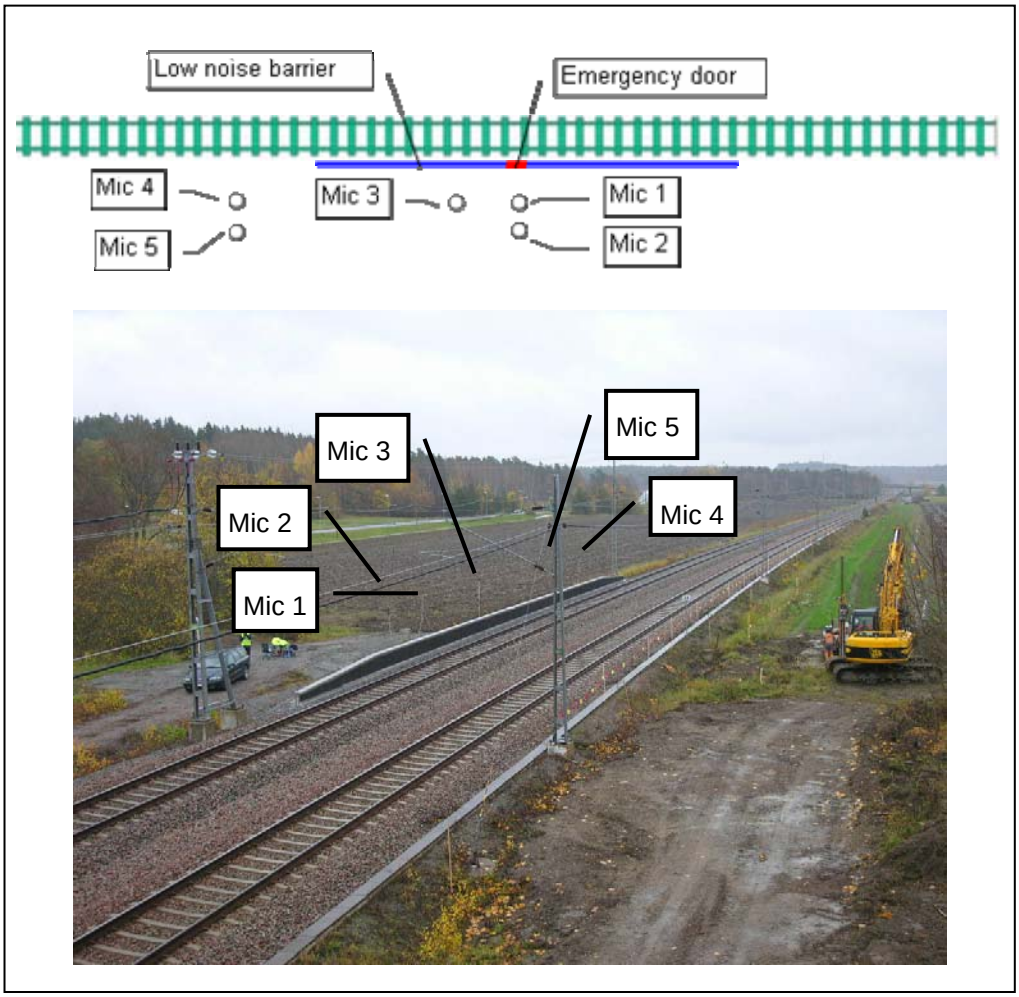


Figure 7.2. Description of measurement site. Five microphones were positioned in three sections

7.2.2 Measurement positions: weather monitoring

The weather monitoring system is shown in Figure 7.3.

Figure 7.3. The VAISALA weather station. The sensor uses ultrasound to measure wind speed and wind direction

7.3 RESULTS

The sound pressure level presented as A-weighted TELs in 1/3 octave band for the 14 registered train passages (different train types) are presented in Appendix 1. A summary of the measured TELs for different train types and passages are presented in Tables 7.2 to Table 7.6.

The speed for all train passages was approximately 70 km/h because of the imposed speed limit on the track. On the test site, many X60 trains were in traffic. Other train types in traffic were X40, InterCity, X12 and one freight train.

Without low barrier, the X60, X40 and X12 trains were approximately 4 dB(A)-units quieter than the InterCity train and 6 dB(A)-units quieter than the freight train.

The low barrier is efficient in reducing TEL levels for the X60 and X12 trains. The measured reduction was 9 dB(A)-units and 7 dB(A)-units, respectively. The barrier is less efficient (4 – 6 dB(A)-units reduction) for the X40, InterCity and freight trains. The reason for this is that the X60 and X12 have rail car sidewalls somewhat enclosing the rail car underneath (bogies not included). This is also true for the X40, although noisy equipment on the train roof restricts the noise reduction.

The combination of a low barrier and trains having noisy equipment enclosed underneath the rail car is thus shown to be an efficient solution to reduce noise. Further, bogie skirts mounted on train would enhance the acoustic performance of the low barrier even more.

The influence of the emergency door on the acoustic performance of the noise barrier is small (<1 dB(A)-unit).

Table 7.2. A summary of TELs for the X60 train passages

Train type	Passage no	Speed km/h	TEL dB(A)				
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
X60	1	65	72	71	72	81	80
X60	2	67	73	72	72	81	80
X60	3	69	72	71	71	81	79
X60	4	64	71	71	71	80	79
X60	5	67	72	72	72	81	79
X60	6	73	72	71	72	81	79
X60	7	68	71	71	71	80	79
X60	8	72	72	72	72	81	79

Table 7.3. A summary of TELs for the X40 train passages

Train type	Passage no	Speed km/h	TEL dB(A)				
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
X40	1	65	76	75	75	81	80
X40	2	67	77	76	77	82	81

Table 7.4. A summary of TELs for the InterCity train passages

Train type	Passage no	Speed km/h	TEL dB(A)				
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
InterCity	1	67	81	80	81	86	84
InterCity	2	64	78	77	78	83	82

Table 7.5. TELs for the X12 train passage

Train type	Passage no	Speed km/h	TEL dB(A)				
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
X12	1	70	75	74	75	82	80

Table 7.6. TELs for the Freight train passage

Train type	Passage no	Speed km/h	TEL dB(A)				
			Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
Freight train	1	66	84	83	84	88	86

In Figure 7.4 and Figure 7.5 the wind speeds and temperatures during the measurements are presented. It can be seen that the maximum wind speed during the measurements were for a few instants slightly higher than the prescribed maximum wind speed in the measurement standard (5 m/s). However, the measured sound levels from the train passages are relatively high compared to the wind induced noise at the microphones and will not influence measurement results.

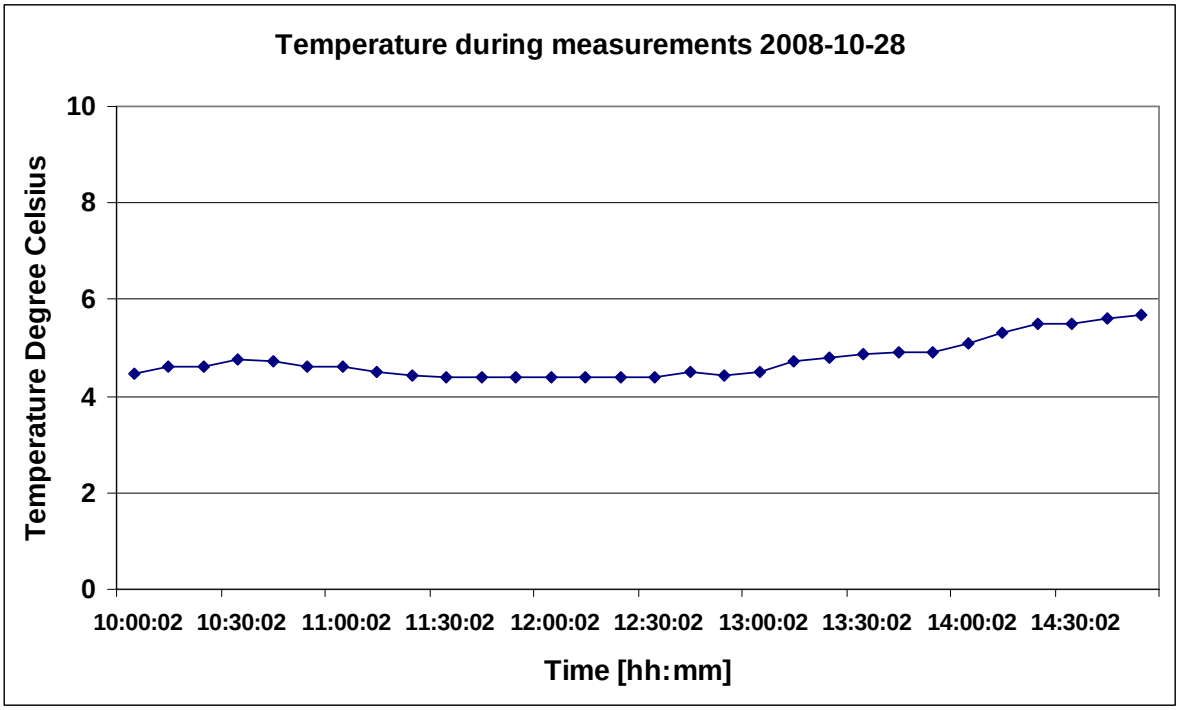


Figure 7.4. Registered temperatures during measurements 2008-10-28

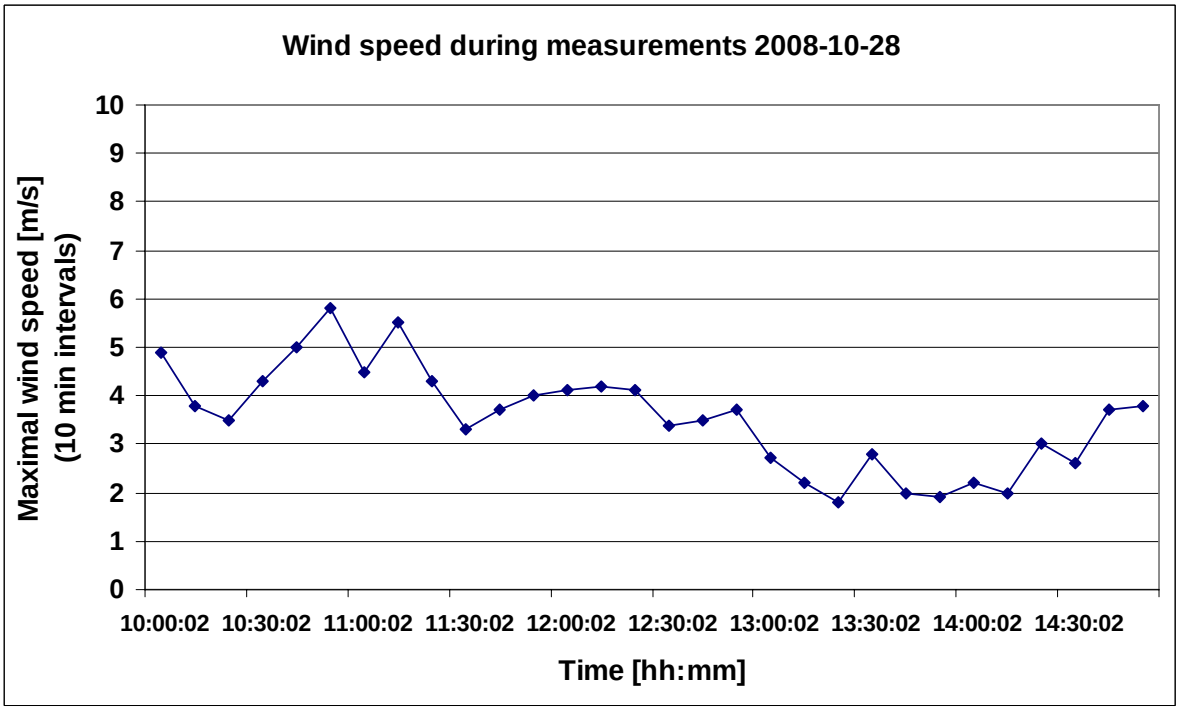


Figure 7.5. Registered maximum wind speeds during measurements 2008-10-28

8 SUMMARY OF RESULTS

In total, noise from 14 train passages (8 X60 trains, 2 X40, 1 X12, 2 InterCity and 1 freight) was recorded. The recorded trains passed the noise barrier with train speeds in the interval 64 – 73 km/h due to the imposed speed restriction.

The X60 trains generated TEL spectra with a maximum in frequency 1/3 octave bands 630 and 800 Hz as generated by remaining grinding marks at wavelengths 2.5 – 3 cm. The conclusion that the X60 wheels are smooth (similar to X2 trailer wheels) seems correct. The freight, X12, X40 and InterCity trains show a broader maximum in TEL spectra from 630 to 2500 Hz.

Without noise barrier, the X60 and X40 trains were the quietest among the trains measured, some 6 dB(A)-units quieter than the freight train. All 8 X60 trains produced a very similar shape of the measured TEL spectrum.

The low barrier is efficient in reducing TEL levels for the X60 and X12 trains. The measured reduction was 9 dB(A)-units and 7 dB(A)-units, respectively. The barrier is less efficient (4 – 6 dB(A)-units reduction) for the X40, InterCity and freight trains. The reason for this is that the X60 and X12 have railcar sidewalls somewhat enclosing the railcar underneath (bogies not included). This is also true for the X40, although noisy equipment on the train roof restricts the noise reduction.

The combination of a low barrier and trains having noisy equipment enclosed underneath the rail car is thus shown to be an efficient solution to reduce railway noise. Further, bogie skirts mounted on train would enhance the performance of the low barrier even more.

The influence of the emergency door in the noise barrier on the generated noise levels is small.

Insertion loss spectra for the different types of train are shown in Figure 8.1.

It is planned to perform new measurements when the speed restriction is lifted. However, due to construction work on the line this unfortunately has to wait until after the end of QCITY.

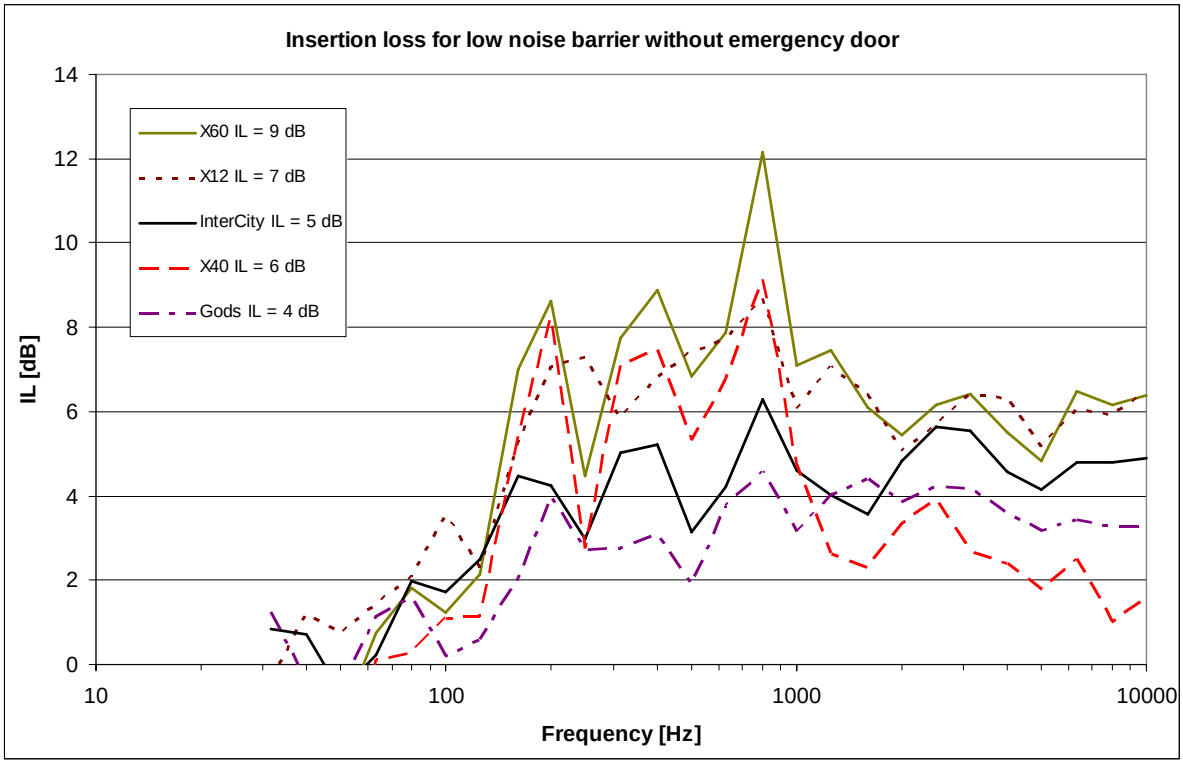


Figure 8.1a. Insertion loss spectra for low noise barrier without emergency door

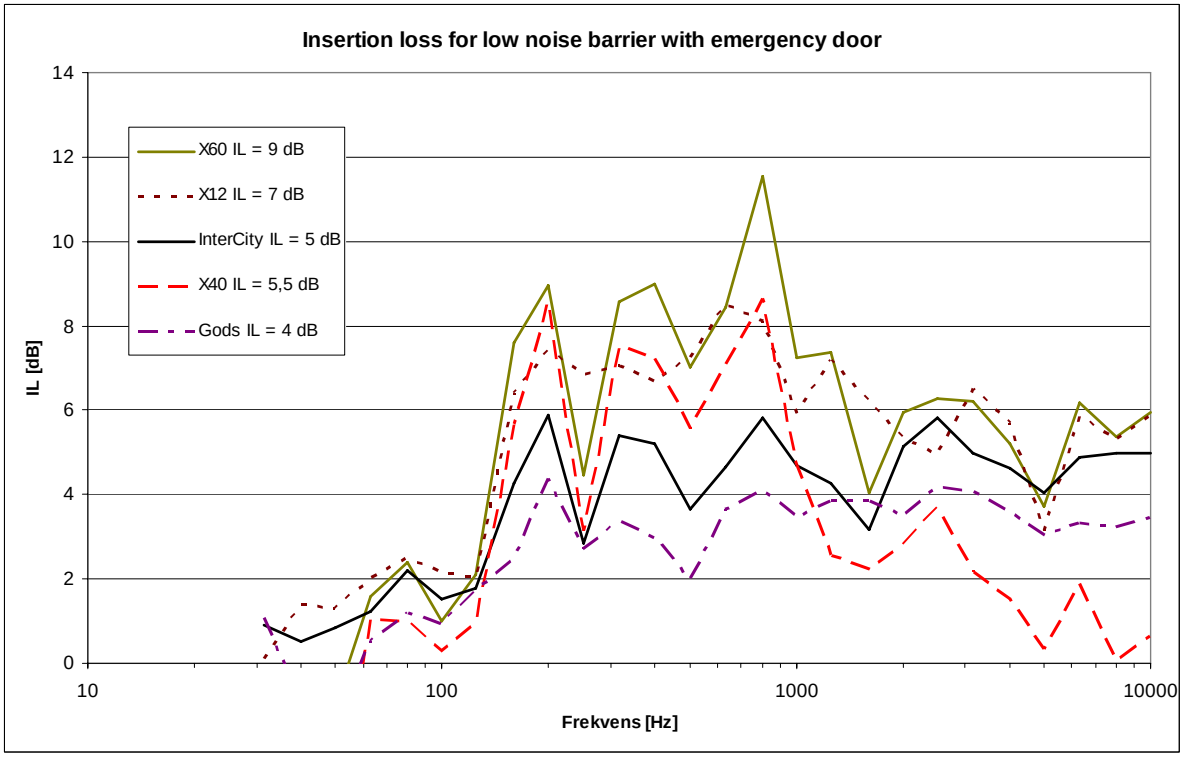


Figure 8.1b. Insertion loss spectra for low noise barrier with emergency door

9 REFERENCES

[1] A Johansson, "Out-of-round railway wheels – assessment of wheel tread irregularities in train traffic", Journal of Sound and Vibration 2006 **293**(3-5) 795-806

[2] TWINS version 3.0 Track-Wheel Interaction Noise Software User´s manual, TNO report HAG-RPT-000020, TNO Institute of Applied Physics, Delft, The Netherlands, 2000

[3] ISO 3095, "Railway applications – Acoustics – Measurement of noise emitted by railbound vehicles (3095:2005)"

[4] Swedish Environmental Protection Agency, report 4935 "Nordic Prediction Method for railway noise"

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

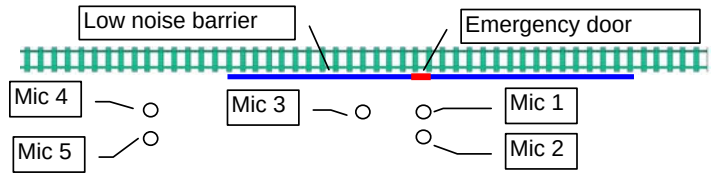
Type of train: Freight train
Passage velocity: 66 km/h
Passage time: 8,2 s
Passage no. for this train type: 1

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

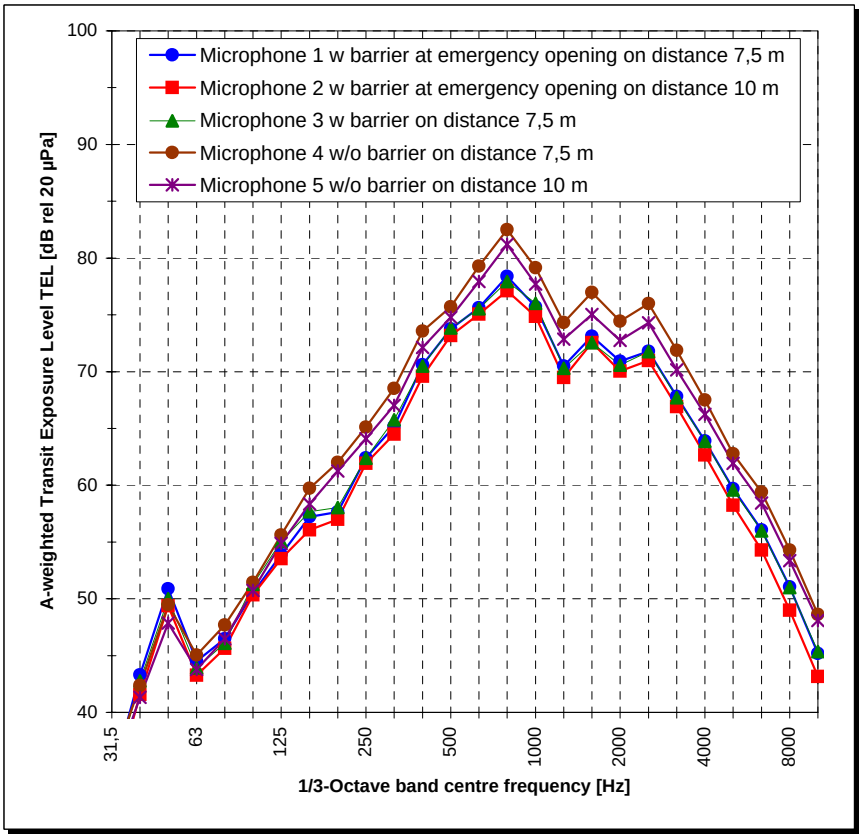
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	34,2	32,6	34,0	35,3	34,3
40	43,3	41,6	42,8	42,4	41,3
50	50,9	49,4	50,0	49,5	47,9
63	44,5	43,3	43,9	45,0	43,8
80	46,5	45,6	46,1	47,7	46,5
100	50,5	50,3	51,3	51,4	50,7
125	53,9	53,5	55,0	55,6	54,9
160	57,2	56,1	57,7	59,7	58,4
200	57,7	57,0	58,0	62,0	61,2
250	62,4	61,9	62,4	65,1	64,1
315	65,2	64,5	65,8	68,5	67,0
400	70,6	69,6	70,5	73,6	72,1
500	73,7	73,2	73,8	75,7	74,8
630	75,6	75,0	75,5	79,3	77,9
800	78,4	77,1	77,9	82,5	81,2
1000	75,7	74,9	76,0	79,2	77,7
1250	70,5	69,5	70,3	74,3	72,9
1600	73,1	72,6	72,6	77,0	75,0
2000	70,9	70,1	70,6	74,4	72,8
2500	71,8	71,0	71,8	76,0	74,3
3150	67,8	66,9	67,7	71,9	70,2
4000	63,9	62,7	63,9	67,5	66,2
5000	59,7	58,2	59,6	62,8	61,9
6300	56,1	54,3	56,0	59,4	58,4
8000	51,0	49,0	51,0	54,3	53,4
10000	45,2	43,1	45,4	48,6	48,1
TEL	**84**	**83**	**84**	**88**	**86**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

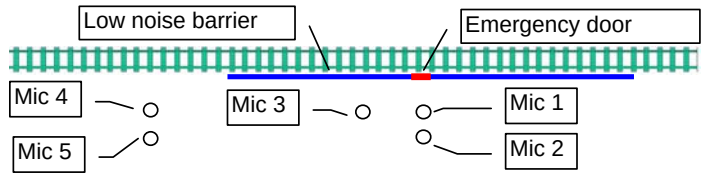
Type of train: X60 commuter train
Passage velocity: 65 km/h
Passage time: 11,4 s
Passage no. for this train type: 1

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

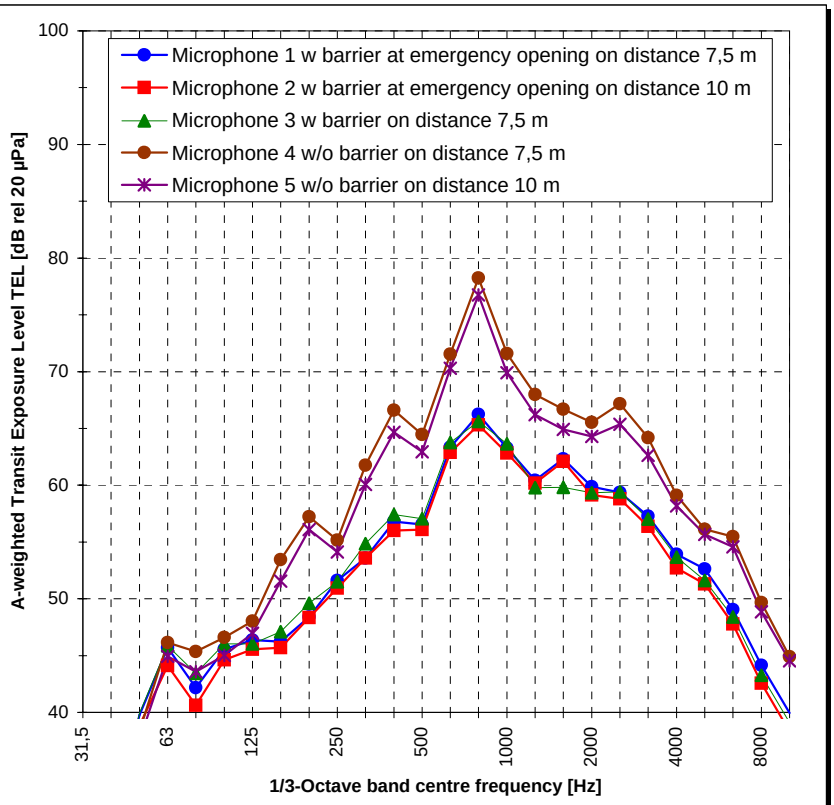
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	24,7	23,8	24,9	25,0	23,9
40	30,0	28,6	29,1	29,3	27,9
50	39,8	38,8	39,9	38,4	37,5
63	45,7	44,1	45,9	46,1	44,9
80	42,2	40,6	43,4	45,4	43,6
100	45,6	44,6	46,0	46,6	45,0
125	46,4	45,6	46,0	48,0	47,0
160	46,2	45,7	47,1	53,5	51,6
200	48,4	48,3	49,6	57,2	56,1
250	51,6	50,9	51,5	55,2	54,1
315	53,6	53,6	54,8	61,8	60,1
400	56,8	56,0	57,4	66,6	64,7
500	56,5	56,1	57,0	64,5	62,9
630	63,3	62,9	63,8	71,5	70,3
800	66,2	65,3	65,6	78,2	76,7
1000	63,3	62,8	63,7	71,6	69,9
1250	60,4	60,2	59,8	68,0	66,2
1600	62,3	62,1	59,8	66,7	64,9
2000	59,9	59,1	59,3	65,5	64,3
2500	59,4	58,8	59,4	67,2	65,4
3150	57,3	56,4	57,0	64,2	62,6
4000	53,9	52,7	53,7	59,1	58,2
5000	52,6	51,3	51,6	56,1	55,7
6300	49,1	47,8	48,4	55,5	54,6
8000	44,2	42,6	43,3	49,7	48,9
10000	39,9	38,3	39,1	44,9	44,5
TEL	**72**	**71**	**72**	**81**	**80**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

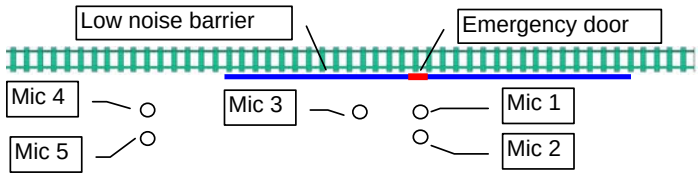
Type of train: InterCity train
Passage velocity: 67 km/h
Passage time: 10,4 s
Passage no. for this train type: 1

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

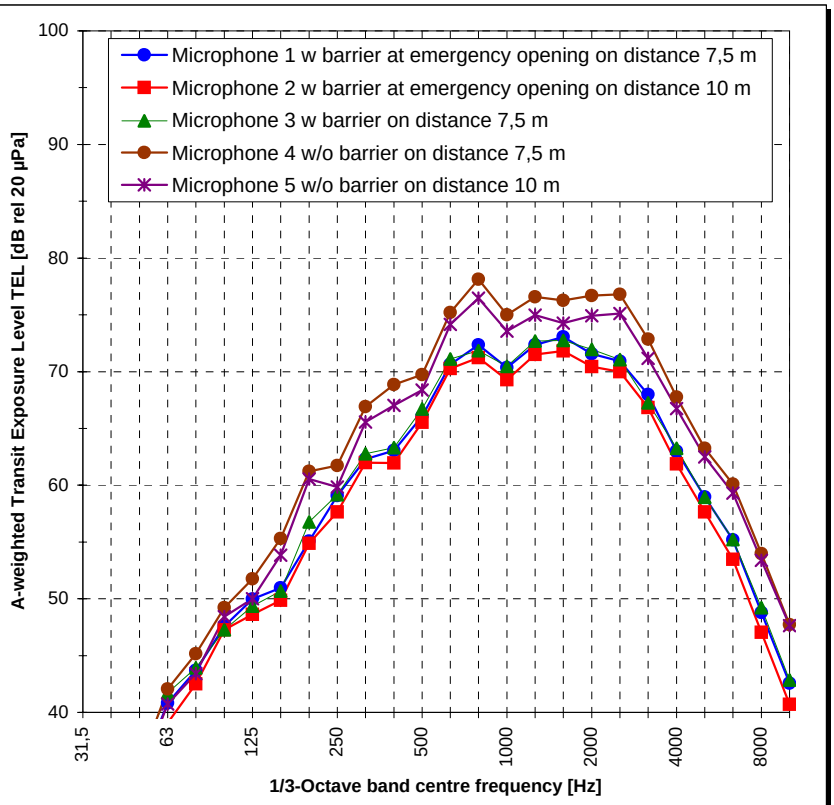
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	30,5	30,4	30,5	31,7	30,2
40	28,8	29,3	28,6	29,3	28,4
50	34,6	34,3	35,8	35,3	34,2
63	40,8	39,1	41,7	42,1	40,7
80	43,7	42,5	43,9	45,2	43,4
100	47,6	47,3	47,3	49,2	48,4
125	50,0	48,6	49,4	51,8	50,0
160	51,0	49,9	50,7	55,3	53,8
200	55,1	54,9	56,8	61,2	60,5
250	59,1	57,6	59,2	61,7	59,8
315	62,3	62,0	62,8	66,9	65,6
400	63,1	61,9	63,3	68,8	67,0
500	66,1	65,5	66,7	69,7	68,4
630	70,6	70,3	71,1	75,2	74,2
800	72,4	71,2	71,8	78,1	76,5
1000	70,3	69,3	70,5	75,0	73,6
1250	72,3	71,5	72,7	76,6	75,0
1600	73,1	71,8	72,7	76,3	74,3
2000	71,6	70,4	72,0	76,7	74,9
2500	70,9	70,0	71,1	76,8	75,1
3150	68,0	66,8	67,3	72,9	71,2
4000	63,0	61,9	63,2	67,8	66,7
5000	59,0	57,6	58,9	63,3	62,5
6300	55,2	53,5	55,2	60,1	59,3
8000	48,8	47,0	49,2	54,0	53,4
10000	42,6	40,7	42,9	47,7	47,6
TEL	**81**	**80**	**81**	**86**	**84**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

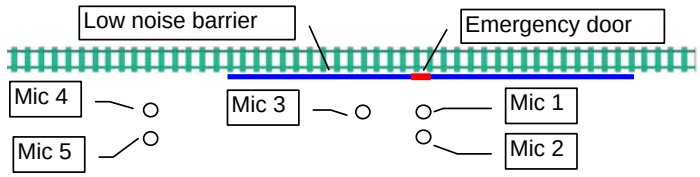
Type of train: X60 commuter train
Passage velocity: 67 km/h
Passage time: 11,1 s
Passage no. for this train type: 2

Background sound level: appr. 55 dB(A)

Measurement equipment

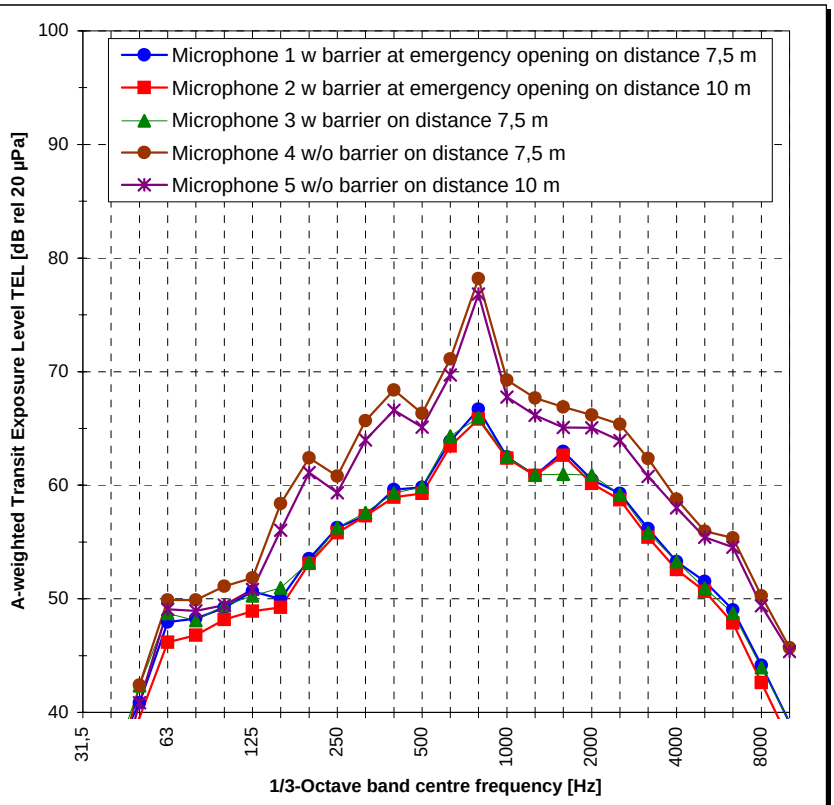
Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	26,5	25,9	27,4	25,7	24,3
40	35,7	34,2	34,9	32,7	31,7
50	40,8	39,6	42,3	42,4	40,8
63	47,9	46,2	48,7	49,9	49,1
80	48,3	46,8	48,1	49,9	48,9
100	49,2	48,2	49,4	51,1	49,4
125	50,7	48,9	50,2	51,8	50,8
160	50,0	49,2	51,0	58,4	56,0
200	53,5	53,1	53,2	62,4	61,1
250	56,3	55,8	56,2	60,8	59,3
315	57,3	57,3	57,6	65,7	64,0
400	59,6	58,9	59,3	68,4	66,6
500	59,8	59,3	59,8	66,3	65,1
630	63,9	63,4	64,3	71,1	69,7
800	66,7	65,8	66,0	78,2	76,8
1000	62,5	62,4	62,5	69,3	67,8
1250	60,9	60,9	60,9	67,7	66,2
1600	63,0	62,6	61,0	66,9	65,1
2000	60,5	60,1	60,9	66,2	65,0
2500	59,3	58,7	59,2	65,4	63,9
3150	56,2	55,4	55,8	62,4	60,8
4000	53,3	52,6	53,3	58,8	58,0
5000	51,5	50,7	50,9	55,9	55,4
6300	49,0	47,9	48,7	55,4	54,5
8000	44,1	42,6	44,0	50,3	49,4
10000	39,1	37,5	39,1	45,7	45,3
TEL	**73**	**72**	**72**	**81**	**80** dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

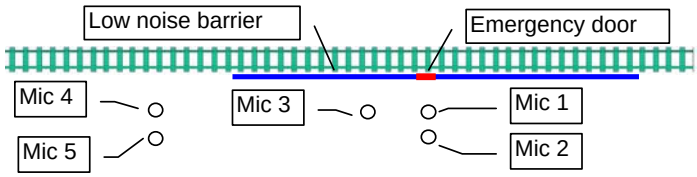
Type of train: X60 commuter train
Passage velocity: 69 km/h
Passage time: 11,1 s
Passage no. for this train type: 3

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

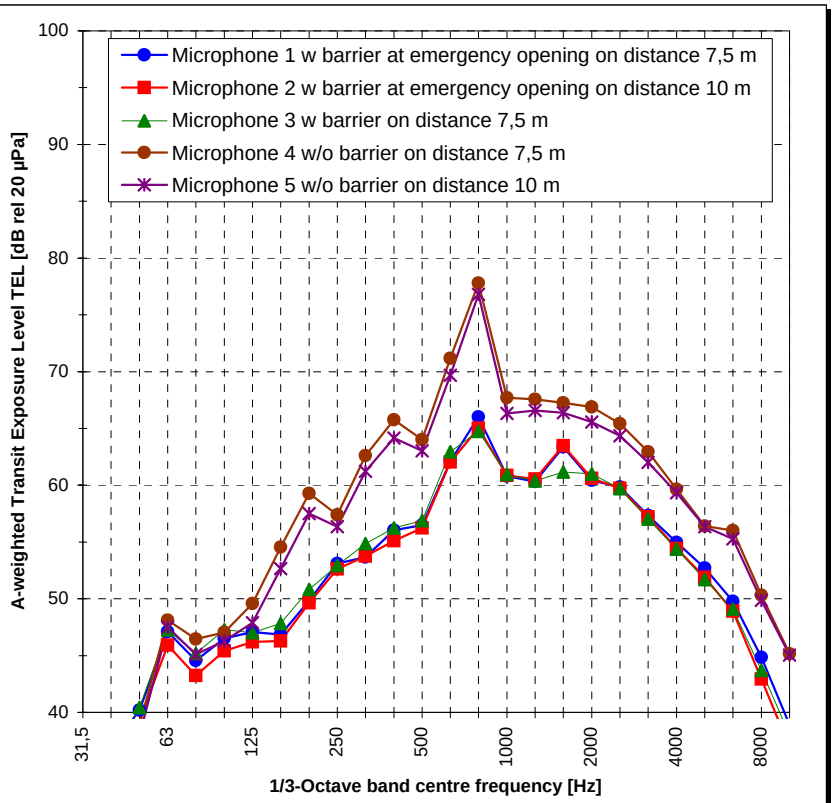
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	27,5	26,6	28,2	27,2	25,6
40	36,8	35,7	35,4	32,5	32,1
50	40,2	39,3	40,4	38,9	38,0
63	47,1	45,9	47,3	48,1	47,5
80	44,6	43,2	45,2	46,5	45,1
100	46,5	45,4	47,3	47,1	46,3
125	47,1	46,2	47,0	49,6	47,9
160	46,8	46,3	47,8	54,5	52,7
200	49,8	49,6	50,8	59,3	57,5
250	53,1	52,6	52,9	57,4	56,3
315	53,7	53,7	54,9	62,6	61,2
400	56,0	55,1	56,2	65,8	64,1
500	56,5	56,2	56,9	64,0	63,0
630	62,1	62,0	63,0	71,2	69,7
800	66,0	65,0	64,7	77,8	76,8
1000	60,8	60,9	60,9	67,7	66,3
1250	60,3	60,6	60,4	67,6	66,6
1600	63,4	63,5	61,2	67,3	66,4
2000	60,4	60,6	61,0	66,9	65,5
2500	59,8	59,7	59,7	65,4	64,3
3150	57,3	57,2	57,0	62,9	62,0
4000	55,0	54,4	54,4	59,6	59,3
5000	52,7	51,9	51,7	56,4	56,3
6300	49,8	48,9	49,1	56,0	55,3
8000	44,9	42,9	43,7	50,3	49,9
10000	38,9	36,9	38,0	45,2	45,0
TEL	**72**	**71**	**71**	**81**	**79**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

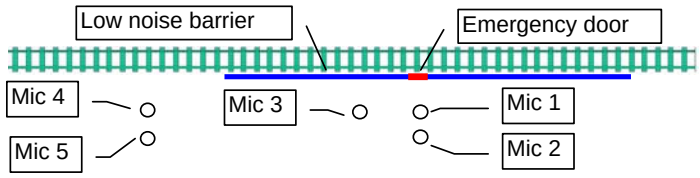
Type of train: X60 commuter train
Passage velocity: 64 km/h
Passage time: 11,6 s
Passage no. for this train type: 4

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

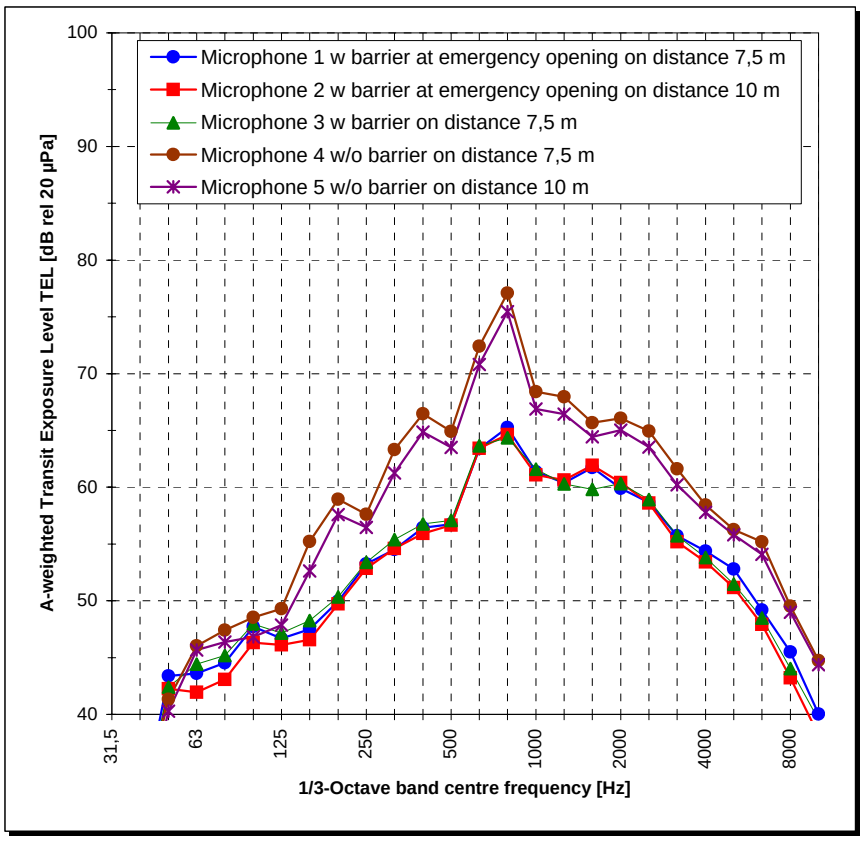
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	24,4	23,5	24,9	24,9	23,8
40	30,9	29,5	30,5	30,9	29,8
50	43,4	42,2	42,4	41,3	40,3
63	43,6	41,9	44,4	46,0	45,7
80	44,5	43,1	45,2	47,4	46,4
100	47,7	46,3	48,0	48,5	46,8
125	46,7	46,1	47,1	49,3	47,9
160	47,5	46,6	48,3	55,2	52,6
200	50,0	49,7	50,3	58,9	57,6
250	53,2	52,8	53,4	57,6	56,5
315	54,5	54,6	55,4	63,3	61,3
400	56,4	55,9	56,8	66,5	64,9
500	56,7	56,6	57,1	64,9	63,5
630	63,4	63,4	63,6	72,4	70,8
800	65,3	64,6	64,3	77,1	75,4
1000	61,4	61,1	61,6	68,4	66,9
1250	60,4	60,6	60,3	68,0	66,4
1600	61,7	61,9	59,8	65,7	64,4
2000	59,9	60,4	60,3	66,1	65,0
2500	58,7	58,6	58,9	64,9	63,5
3150	55,7	55,2	55,7	61,6	60,2
4000	54,4	53,4	53,8	58,4	57,8
5000	52,8	51,2	51,5	56,2	55,8
6300	49,2	47,9	48,5	55,2	54,1
8000	45,5	43,2	44,0	49,5	49,0
10000	40,0	38,2	39,5	44,7	44,4
TEL	**71**	**71**	**71**	**80**	**79**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

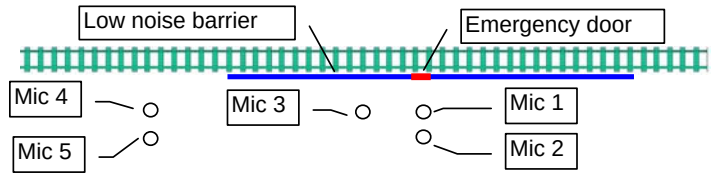
Type of train: X40 Regional train
Passage velocity: 65 km/h
Passage time: 4,4 s
Passage no. for this train type: 1

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

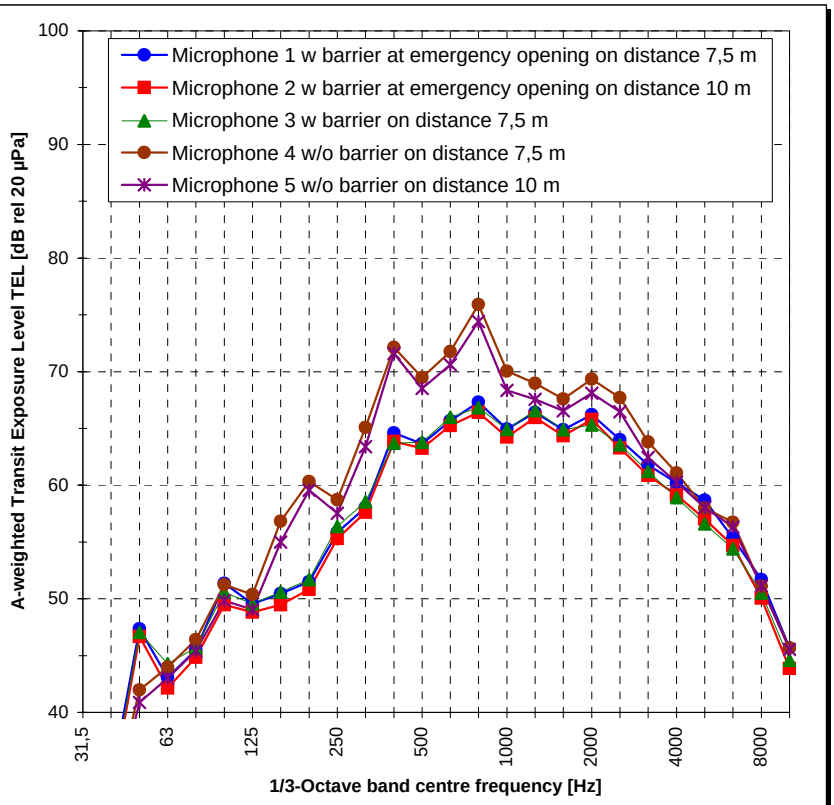
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	27,3	26,7	27,6	26,2	26,0
40	33,9	32,7	33,2	31,6	30,9
50	47,3	46,7	47,1	42,0	40,9
63	43,1	42,2	44,3	44,0	43,0
80	45,5	44,8	45,7	46,4	45,4
100	51,3	49,5	50,6	51,3	49,8
125	49,5	48,8	49,6	50,4	49,1
160	50,4	49,5	50,6	56,8	55,0
200	51,5	50,8	51,7	60,3	59,6
250	55,8	55,3	56,4	58,7	57,5
315	58,0	57,6	58,5	65,1	63,4
400	64,6	63,8	63,7	72,1	71,6
500	63,7	63,2	63,8	69,5	68,5
630	65,7	65,2	66,0	71,8	70,6
800	67,3	66,4	66,8	75,9	74,4
1000	64,9	64,2	64,9	70,0	68,4
1250	66,4	66,0	66,6	69,0	67,6
1600	64,9	64,4	64,9	67,6	66,6
2000	66,2	65,8	65,3	69,3	68,1
2500	64,0	63,3	63,6	67,7	66,5
3150	61,8	60,8	61,2	63,8	62,4
4000	60,2	59,1	58,9	61,1	60,3
5000	58,7	57,0	56,6	58,0	58,0
6300	55,4	54,7	54,4	56,8	56,3
8000	51,7	50,0	50,5	51,1	51,1
10000	45,7	43,8	44,6	45,7	45,6
TEL	**76**	**75**	**75**	**81**	**80**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

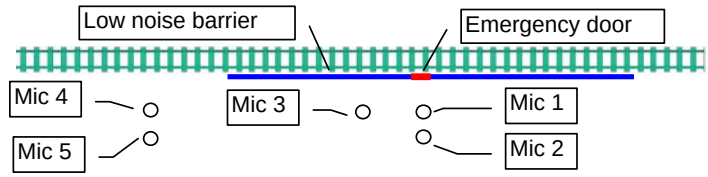
Type of train: X60 commuter train
Passage velocity: 67 km/h
Passage time: 11,0 s
Passage no. for this train type: 5

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

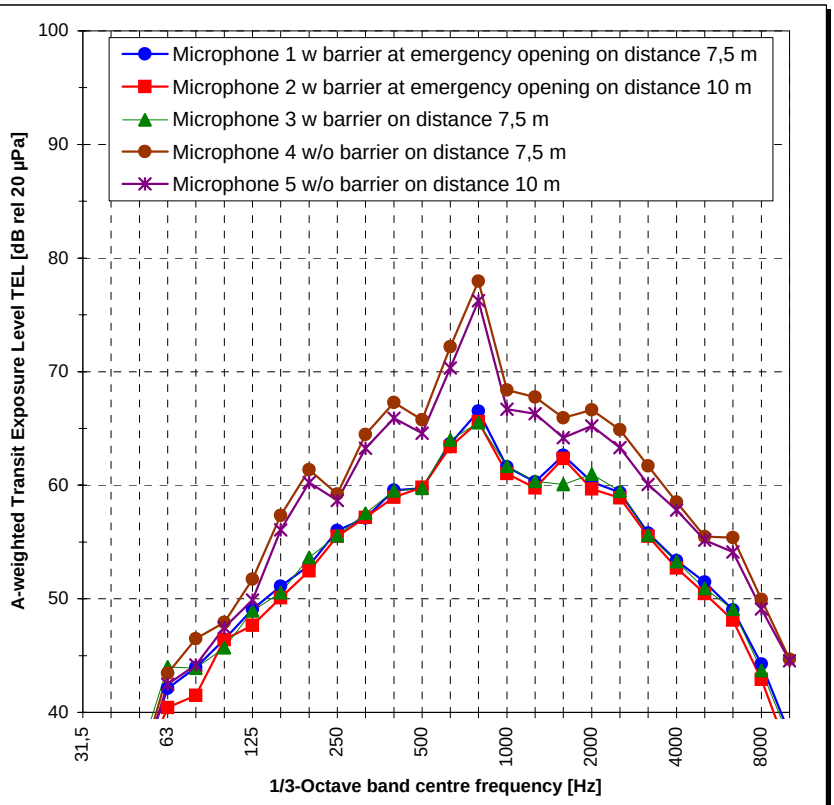
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	23,8	23,2	24,8	23,2	22,4
40	29,1	28,6	29,0	28,5	28,2
50	34,9	34,7	36,2	34,9	34,5
63	42,1	40,4	44,0	43,4	42,5
80	43,9	41,5	43,9	46,5	44,2
100	46,4	46,4	45,7	47,9	47,5
125	49,1	47,7	48,9	51,7	49,9
160	51,1	50,1	50,5	57,3	56,1
200	52,9	52,5	53,6	61,4	60,2
250	56,0	55,5	55,6	59,2	58,6
315	57,1	57,2	57,5	64,5	63,3
400	59,6	58,9	59,5	67,3	65,9
500	59,7	59,8	59,7	65,8	64,6
630	63,6	63,4	64,0	72,2	70,3
800	66,5	65,6	65,5	78,0	76,3
1000	61,6	61,0	61,7	68,4	66,7
1250	60,3	59,8	60,3	67,8	66,3
1600	62,6	62,4	60,1	65,9	64,2
2000	60,3	59,7	61,0	66,6	65,2
2500	59,4	58,9	59,5	64,9	63,3
3150	55,8	55,5	55,6	61,7	60,1
4000	53,3	52,7	53,3	58,5	57,8
5000	51,5	50,5	50,9	55,5	55,2
6300	49,0	48,1	49,1	55,4	54,1
8000	44,3	42,9	43,7	50,0	49,1
10000	38,1	36,2	37,7	44,7	44,5
TEL	**72**	**72**	**72**	**81**	**79**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

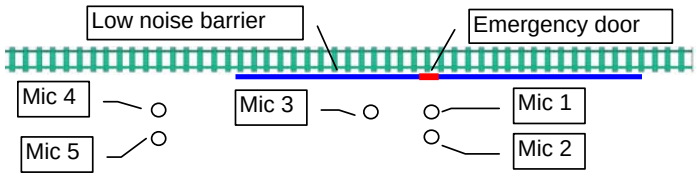
Type of train: InterCity train
Passage velocity: 64 km/h
Passage time: 15,1 s
Passage no. for this train type: 2

Background sound level: appr. 55 dB(A)

Measurement equipment

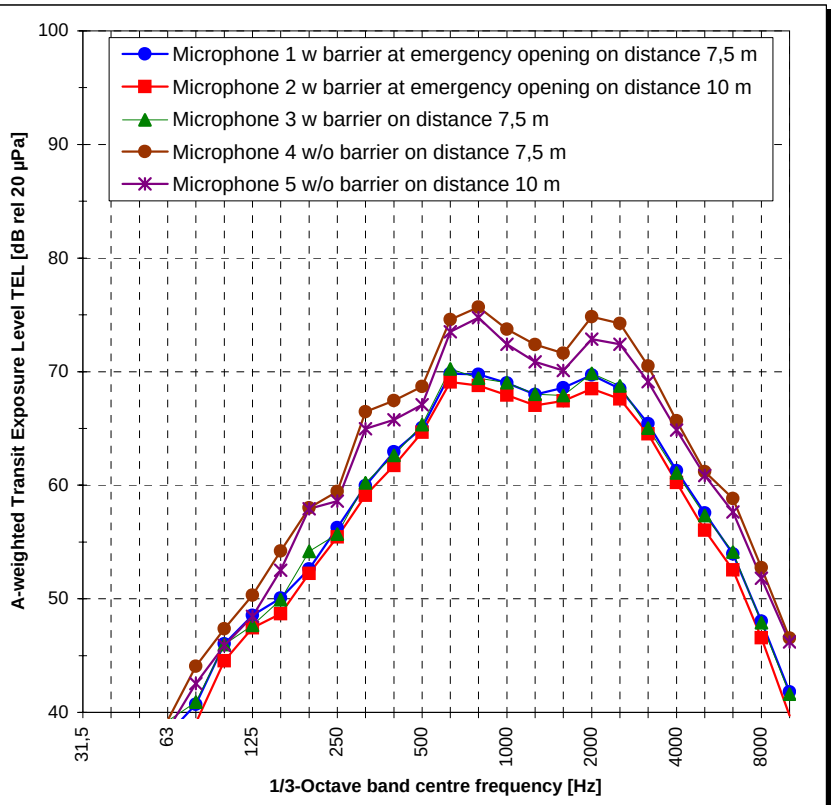
Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	27,0	25,6	27,0	27,1	25,7
40	26,7	25,4	26,7	27,2	26,1
50	33,7	32,1	35,6	34,7	33,1
63	38,0	36,5	39,2	39,3	38,4
80	40,7	39,1	40,9	44,1	42,6
100	46,0	44,5	46,0	47,4	45,9
125	48,5	47,4	47,7	50,3	48,5
160	50,1	48,7	49,9	54,2	52,5
200	52,6	52,2	54,2	58,0	57,9
250	56,3	55,4	55,7	59,4	58,6
315	59,9	59,1	60,2	66,5	65,0
400	62,9	61,7	62,6	67,5	65,8
500	65,1	64,6	65,3	68,7	67,1
630	69,8	69,1	70,2	74,6	73,5
800	69,8	68,8	69,4	75,7	74,7
1000	69,0	67,9	69,0	73,7	72,4
1250	68,0	67,0	68,0	72,4	70,9
1600	68,6	67,4	67,9	71,6	70,1
2000	69,7	68,5	69,8	74,8	72,9
2500	68,5	67,6	68,7	74,2	72,4
3150	65,4	64,5	65,0	70,5	69,1
4000	61,3	60,2	61,1	65,7	64,9
5000	57,5	56,0	57,3	61,2	60,8
6300	54,0	52,5	54,1	58,8	57,7
8000	48,0	46,6	47,9	52,7	51,8
10000	41,8	39,7	41,6	46,5	46,2
TEL	**78**	**77**	**78**	**83**	**82** dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

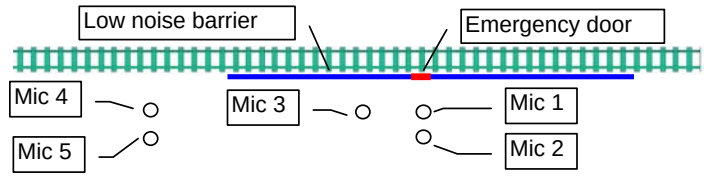
Type of train: X12 commuter train
Passage velocity: 70 km/h
Passage time: 10,3 s
Passage no. for this train type: 1

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

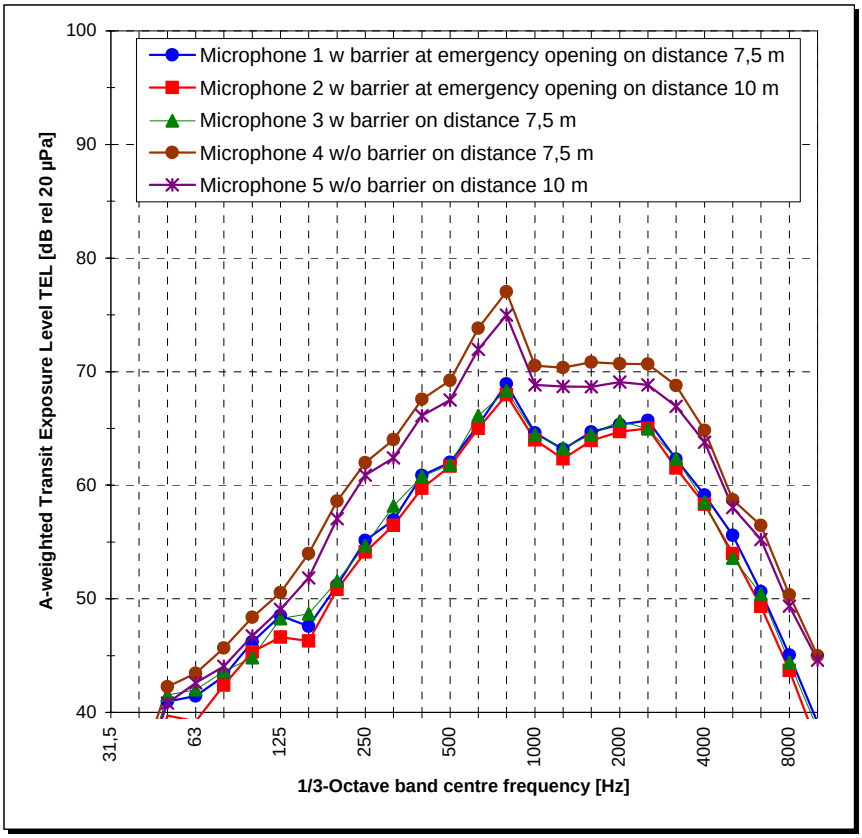
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	30,1	28,5	30,6	30,2	29,8
40	33,4	32,0	33,6	34,8	34,0
50	40,9	39,7	41,5	42,2	40,8
63	41,4	39,2	42,0	43,4	42,6
80	43,2	42,4	43,6	45,7	44,1
100	46,2	45,3	44,8	48,4	46,7
125	48,5	46,6	48,2	50,5	49,1
160	47,6	46,3	48,7	54,0	51,8
200	51,2	50,8	51,5	58,6	57,1
250	55,1	54,1	54,7	62,0	60,9
315	56,9	56,4	58,2	64,0	62,4
400	60,9	59,7	60,8	67,6	66,1
500	62,0	61,7	61,8	69,2	67,5
630	65,3	65,0	66,1	73,8	72,0
800	68,9	68,0	68,3	77,0	75,0
1000	64,6	64,0	64,5	70,5	68,8
1250	63,2	62,3	63,3	70,3	68,7
1600	64,7	63,9	64,5	70,8	68,7
2000	65,3	64,7	65,6	70,7	69,1
2500	65,7	65,0	65,0	70,7	68,8
3150	62,3	61,5	62,3	68,8	66,9
4000	59,1	58,3	58,5	64,8	63,8
5000	55,6	54,0	53,6	58,7	58,0
6300	50,6	49,3	50,4	56,5	55,2
8000	45,0	43,7	44,4	50,3	49,4
10000	39,1	37,2	38,5	45,0	44,6
TEL	**75**	**74**	**75**	**82**	**80**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

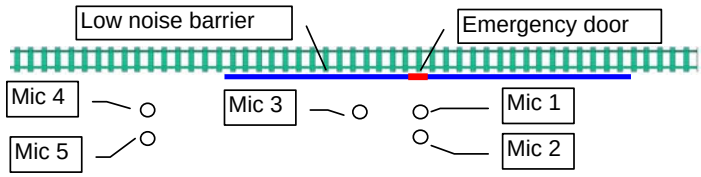
Type of train: X60 commuter train
Passage velocity: 73 km/h
Passage time: 10,5 s
Passage no. for this train type: 6

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

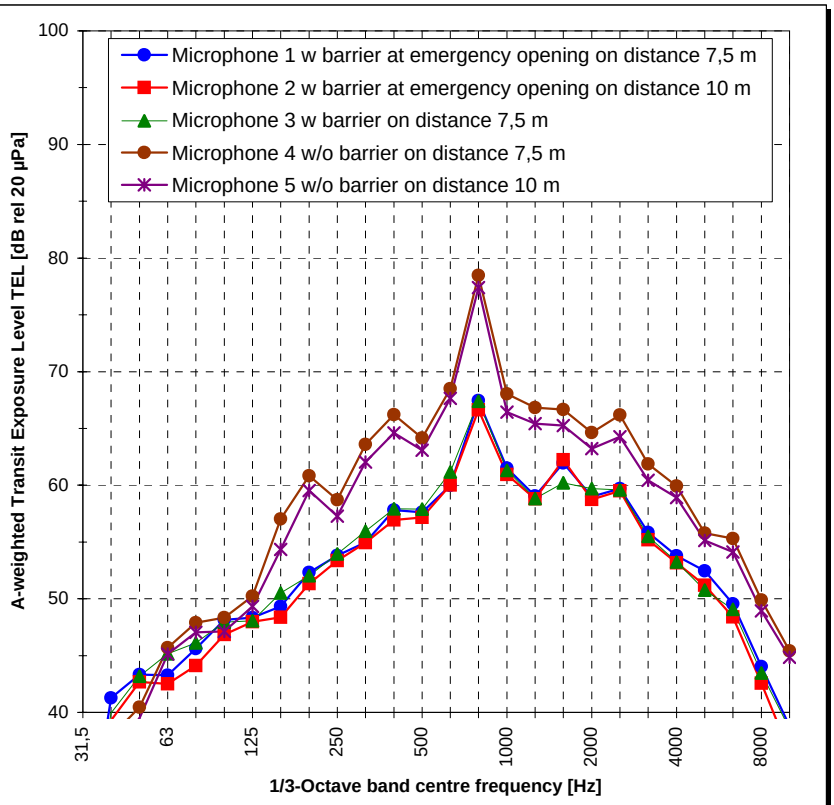
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	25,4	23,8	25,6	24,0	23,0
40	41,3	39,3	39,9	37,9	36,7
50	43,3	42,7	43,2	40,5	39,5
63	43,3	42,5	45,2	45,7	45,1
80	45,6	44,1	46,1	47,9	47,0
100	48,1	46,9	47,9	48,4	47,1
125	48,3	48,0	48,1	50,2	49,3
160	49,3	48,4	50,5	57,0	54,4
200	52,3	51,3	52,0	60,8	59,5
250	53,8	53,4	54,0	58,7	57,3
315	55,0	54,9	55,9	63,6	62,0
400	57,8	56,9	57,9	66,2	64,6
500	57,6	57,2	57,9	64,1	63,1
630	60,0	60,0	61,2	68,5	67,6
800	67,4	66,6	67,4	78,5	77,4
1000	61,5	60,9	61,3	68,1	66,4
1250	59,1	58,8	58,8	66,8	65,4
1600	62,0	62,2	60,2	66,7	65,3
2000	59,0	58,8	59,7	64,6	63,2
2500	59,7	59,5	59,6	66,2	64,3
3150	55,9	55,2	55,5	61,9	60,4
4000	53,8	53,2	53,3	59,9	58,9
5000	52,4	51,2	50,8	55,8	55,1
6300	49,6	48,4	49,1	55,3	54,1
8000	44,0	42,6	43,5	49,9	48,9
10000	38,8	36,5	38,5	45,4	44,9
TEL	**72**	**71**	**72**	**81**	**79**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

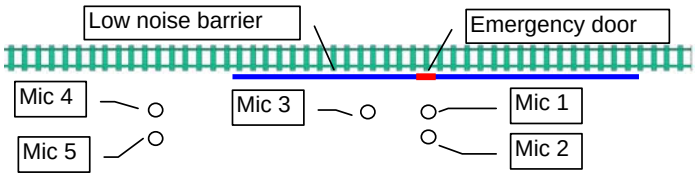
Type of train: X40 regional train
Passage velocity: 67 km/h
Passage time: 7,3 s
Passage no. for this train type: 2

Background sound level: appr. 55 dB(A)

Measurement equipment

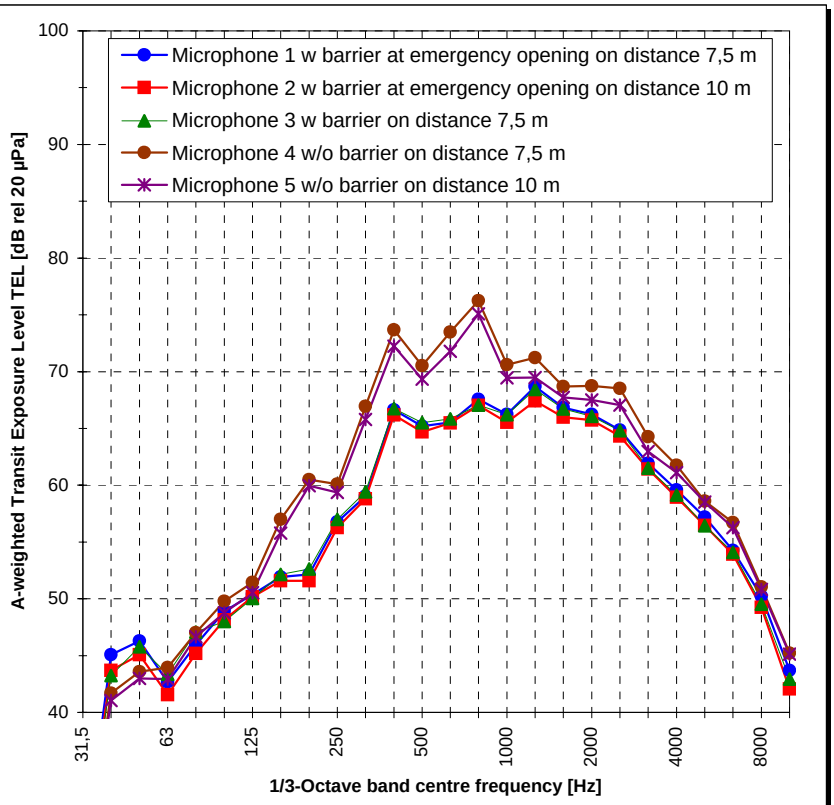
Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	26,4	26,0	25,8	24,7	23,9
40	45,1	43,7	43,2	41,7	41,0
50	46,3	45,1	45,8	43,6	43,0
63	42,7	41,6	43,3	44,0	42,9
80	45,9	45,2	47,1	47,0	46,6
100	48,9	48,1	48,0	49,8	48,8
125	50,4	50,2	50,0	51,4	50,5
160	51,9	51,6	52,2	57,0	55,8
200	52,2	51,6	52,6	60,5	59,9
250	56,8	56,3	57,0	60,1	59,4
315	59,0	58,8	59,4	66,9	65,8
400	66,6	66,2	66,8	73,7	72,2
500	65,2	64,7	65,5	70,5	69,3
630	65,5	65,5	65,8	73,5	71,8
800	67,6	67,0	67,0	76,2	75,1
1000	66,2	65,5	66,2	70,6	69,5
1250	68,7	67,4	68,4	71,2	69,5
1600	66,8	66,0	66,7	68,7	67,7
2000	66,2	65,7	66,1	68,8	67,5
2500	64,9	64,3	64,8	68,5	67,1
3150	61,9	61,4	61,5	64,3	63,0
4000	59,6	58,9	59,1	61,8	61,1
5000	57,2	56,5	56,4	58,6	58,5
6300	54,3	53,9	54,1	56,7	56,3
8000	50,2	49,2	49,5	51,0	50,8
10000	43,7	42,1	42,9	45,2	45,1
TEL	**77**	**76**	**77**	**82**	**81** dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

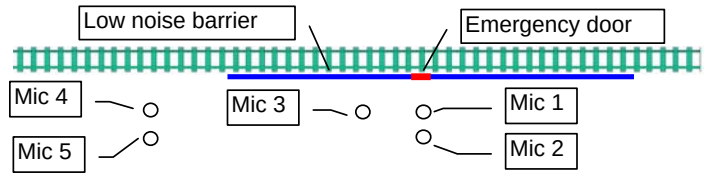
Type of train: X60 commuter train
Passage velocity: 68 km/h
Passage time: 11,3 s
Passage no. for this train type: 7

Background sound level: appr. 55 dB(A)

Measurement equipment

Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

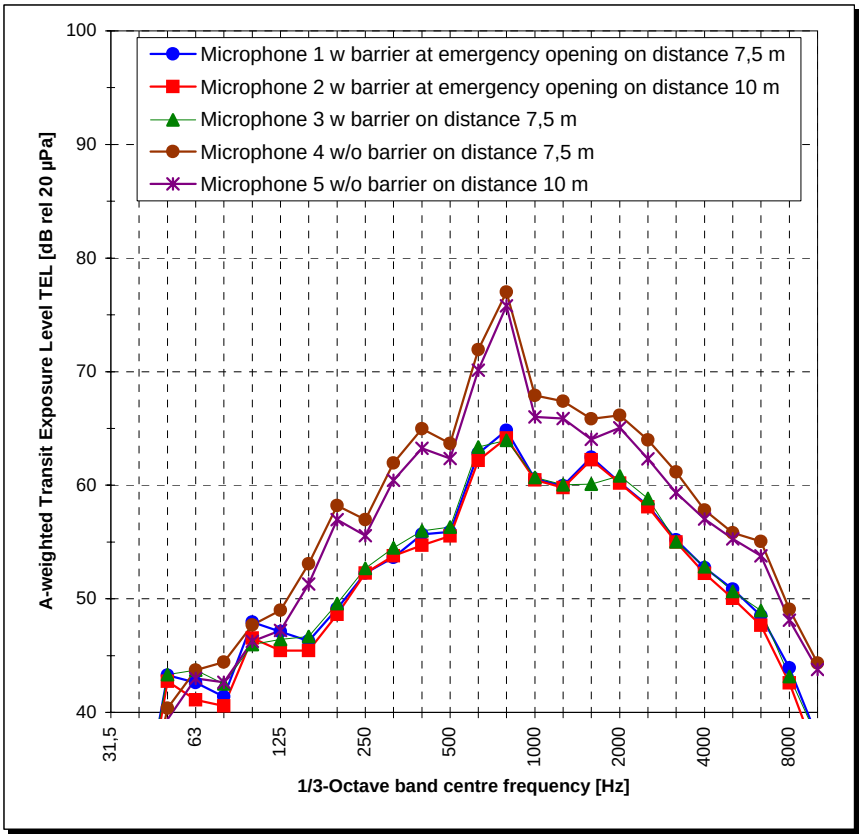
Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	23,5	22,5	23,9	23,4	21,9
40	29,5	28,3	29,1	28,8	27,2
50	43,3	42,7	43,3	40,4	39,4
63	42,6	41,1	43,7	43,7	43,0
80	41,4	40,6	42,5	44,4	42,7
100	47,9	46,5	46,0	47,7	46,3
125	47,1	45,4	46,4	49,0	47,2
160	46,3	45,4	46,7	53,1	51,3
200	49,1	48,6	49,6	58,2	57,0
250	52,3	52,2	52,7	57,0	55,6
315	53,6	53,8	54,5	62,0	60,4
400	55,7	54,7	56,0	65,0	63,2
500	55,9	55,5	56,3	63,7	62,4
630	62,8	62,2	63,4	71,9	70,1
800	64,8	64,1	64,0	77,0	75,8
1000	60,6	60,5	60,7	67,9	66,0
1250	59,9	59,8	60,0	67,4	65,9
1600	62,5	62,2	60,1	65,8	64,0
2000	60,2	60,2	60,8	66,1	65,1
2500	58,2	58,1	58,8	64,0	62,3
3150	55,2	55,0	55,0	61,2	59,3
4000	52,7	52,2	52,8	57,8	57,0
5000	50,9	50,0	50,7	55,8	55,3
6300	48,5	47,7	49,0	55,0	53,8
8000	43,9	42,6	43,2	49,1	48,1
10000	37,8	36,0	37,7	44,3	43,8
TEL	**71**	**71**	**71**	**80**	**79**

dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.

Sound pressure levels from train passages

CONTRACT N^{O}	TIP4-CT-2005-516420	APPENDIX	PERFORMED BY	Measurement date
PROJECT N^{O}	FP6-516420	**1**	O Lundberg / G Larsson (ACL)	2008-10-28
ACRONYM	QCITY			

Sound measurements on test site with low noise barrier close to track.

TEL (Transit Exposure Level)

Applied measurement standard: ISO 3095:2005

TEST OBJECT

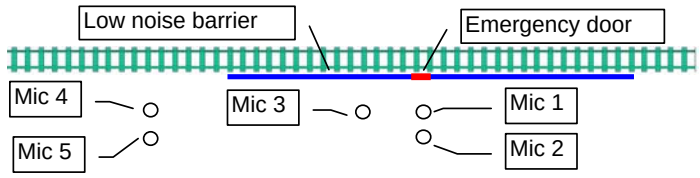
Type of train: X60 commuter train
Passage velocity: 72 km/h
Passage time: 10,7 s
Passage no. for this train type: 8

Background sound level: appr. 55 dB(A)

Measurement equipment

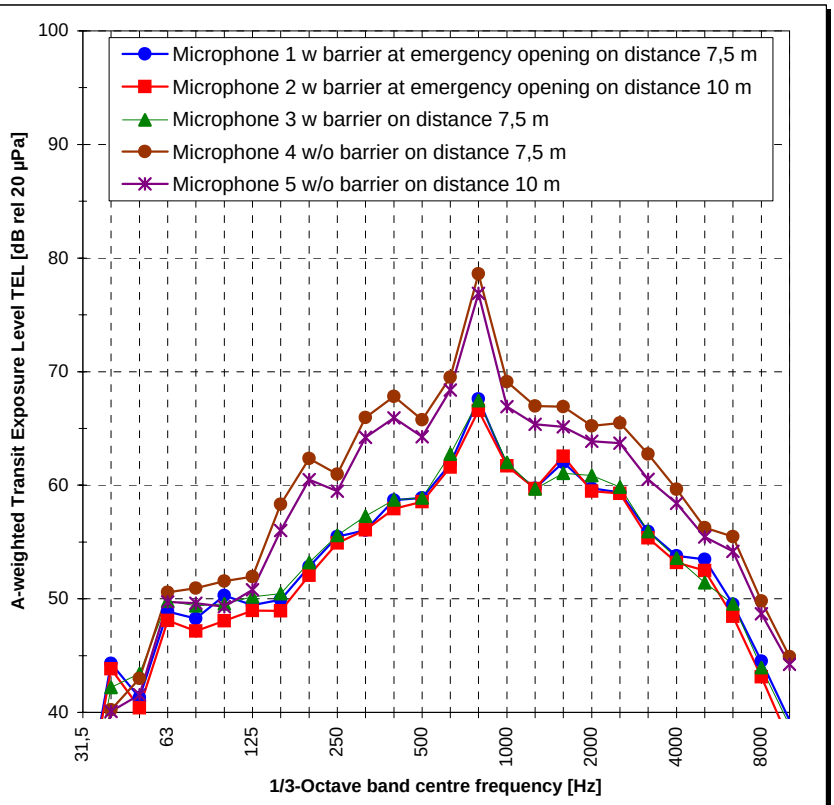
Front-end: Brüel & Kjaer PULSE
Microphone: Brüel & Kjaer 4189
Sound level calibrator: Norsonic CAL 022, SN 29978

Sketch of measurement site



Microphone 1, 3 & 4 are positioned 7.5 m from the track centre and 1.2 m above rail upper surface. Microphone 2 & 5 are positioned 10 m from the track centre and 2 m above ballast.

Frequency [Hz]	A-weighted Transit Exposure Level TEL [dB]				
	Mic 1	Mic 2	Mic 3	Mic 4	Mic 5
31,5	30,5	30,0	28,9	28,2	27,0
40	44,3	43,8	42,2	40,2	40,1
50	41,3	40,4	43,4	43,0	41,5
63	48,9	48,1	49,8	50,6	49,7
80	48,2	47,2	49,4	50,9	49,6
100	50,3	48,1	49,6	51,5	49,3
125	49,5	49,0	50,2	52,0	50,8
160	49,9	48,9	50,5	58,3	56,0
200	52,8	52,1	53,2	62,3	60,5
250	55,5	54,9	55,6	61,0	59,5
315	56,0	56,1	57,3	65,9	64,2
400	58,7	57,9	58,7	67,8	65,9
500	58,9	58,6	58,9	65,8	64,3
630	61,9	61,6	62,7	69,5	68,4
800	67,6	66,6	67,5	78,6	76,9
1000	61,7	61,7	62,0	69,1	66,9
1250	59,7	59,7	59,7	67,0	65,4
1600	62,0	62,5	61,0	66,9	65,2
2000	59,7	59,5	60,8	65,2	63,9
2500	59,4	59,3	59,8	65,5	63,7
3150	55,9	55,4	55,9	62,8	60,5
4000	53,8	53,2	53,6	59,7	58,4
5000	53,5	52,5	51,4	56,3	55,5
6300	49,5	48,5	49,5	55,5	54,2
8000	44,5	43,1	44,0	49,8	48,7
10000	39,3	37,4	38,9	44,9	44,2
TEL	**72**	**72**	**72**	**81**	**79** dB(A)



Comment

The TEL levels are corrected for the rail and wheel roughness.