Train pass-by noise - measurement procedure

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1 Introduction

Experimental measurements of train pass-by noise were conducted in the context of a student's project [1] near the city of Braunschweig, Germany. In total, 41 train pass-by events were measured in one day (22nd April, 2020). These include different types of trains, e.g. regional, long-distance and cargo trains, with different number of wagons, velocities and heading to different directions. All measured sound files are made available for use with no restrictions. In this document, the an overview about the measurement procedure is provided. **Moreover, videos and photos of each individual train pass-by event are available and can be shared under request**[1].

1.1 Measurement location

The experimental measurements of train noise were conducted at a high frequented rail track near the city of Braunschweig. After consulting the map available by the *Eisenbahnbundesamt* [2], where the rail tracks and corresponding estimated noise levels all over Germany can be verified, a location near Timmerlah - a village in the west direction from the city of Braunschweig - was chosen for the measurements. It is located directly next to a rail track segment where trains heading to the West (Braunschweig –> Hannover) and East (Hannover –> Braunschweig) directions pass. The tracks are in good conditions and in that segment going straight ahead. There is neither much environmental noise nearby nor a noise protection wall but only free fields on the surroundings.

At the measurement location there are three rails and trains are going in two opposite directions. Therefore, only recordings of trains passing by on the closest rail (rail 1, as showed in Figure 1) comply with the requirement of

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the DIN ISO 3095 [3] (i.e. distance of 7.50 m from the center of the considered rail). The velocity of the different trains was not measured nor estimated, so there might be a variation of speed for different recordings of the same type of train. Moreover, one may not expect that all the measurements were started with the trains on the same position. Additionally to the acoustic measurements, videos of the passing trains were made so that afterwards the sound files could be associated to the trains and classified by categories like type of train or number of wagons.

Figure 1: Measurement location: left - close-up view and rail denominations; right - overall view of the location. Source: from Ref. [1].

On the day of the measurements, the weather was sunny with a temperature of about 20 °C in the shade, air pressure of 1.024 mbar and a relative humidity of 34 %. There was wind coming from the east with a velocity of around 23 km/h. Nevertheless, the atmospheric conditions were not measured but only estimated on the internet.

1.2 Measurement setup

A Brüel & Kjaer 1/2 inch free-field condenser microphone type 4191 with a wind shield was used for the measurements. The microphone was positioned according to DIN ISO 3095 [3] - the norm for the measurement of noise emitted by railbound vehicles - at a height of 1.20 m above the ground and at distance of $\approx$ 7.50 m from the center of rail 1. It was connected to a 'ROGA Plug.n.DAQ Lite', responsible to convert the analogue signal from the microphone to digital, which was then sent to the computer via USB input where the sound files were recorded with the open-source software 'Audacity'. All measurements were conducted with the same setup and configurations.

1.3 Calibration

For the purpose of calibrating the recorded signals, three measurements of a calibration signal from a Brüel & Kjaer 'Sound Calibrator Type 4231' were conducted during the measurement campaign. For this purpose, calibration signals with 94 dB SPL (1 Pa) and a frequency of 1 kHz were recorded. The same setup and configurations were used during the entire measurement campaign.

1.4 Background noise

Several records of the background noise were made at different times during the measurement campaign. The background noise was mainly composed by passing cars and occasional birds flying nearby. Figure 2 presents the loudness of one exemplary background noise recording in comparison with the loudness of train 1, both computed according to the Zwicker loudness model using the software provided by the ISO 532-1 [4].

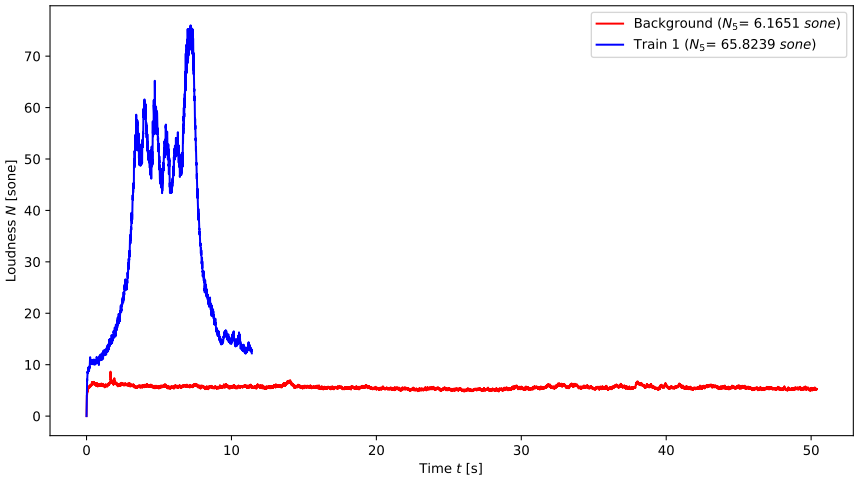

Figure 2: Loudness of environmental noise and train 1 over time. Source: from Ref. [1].

The exemplary case shown in Figure 2 is considered to be representative as the background noise was relatively constant during the whole measurement campaign. It is noticeable that the train noise (represented by the blue curve) is much louder than the environmental noise (represented by the red curve) which is rather steady and stays consistently below 10 sone for its entire

duration. The background noise has a 5% percentile loudness, N_5, value of 6.17 sone. Therefore, the train pass-by event, in this case, is about ten times louder than the background noise. As the background noise is relatively quiet and steady, it did not significantly interfere in the loudness calculation of the train pass-by events, shown by the fact that the behaviour of the train noise curve is clearly recognizable.

1.5 Description of sound files

The files were named according to the direction on which the recorded trains were heading to and in a sequential way. The following convention was adopted:

- train_xx - recordings of trains heading West - direction Braunschweig –> Hannover. These train pass-by events occured mostly in rail 1 (i.e. approx. 7.5 meters from the microphone). Exceptions are trains 8, 13, 19 and 22 as they were passing in rail 3;
- train_otherside_xx - recordings of trains heading East - direction Hannover –> Braunschweig. These train pass-by events occurred mostly in rail 2. Exceptions are trains 5, 8, 10 and 13 as they were passing in rail 3;
- train_both_sides - one event which two cargo trains were passing at the same time. One train was passing in rail 2 (direction Hannover –> Braunschweig) and the other on rail 1 (direction Braunschweig –> Hannover);
- calibration_xx - recordings of a calibration tone (94 dB SPL @ 1 kHz). See Section 1.3 for more details;
- background_xx - arbitrary recordings of the background noise. See Section 1.4 for more details.

The table shown in Figure 3 present an overview of all the measured train pass-by events which were heading West - direction Braunschweig –> Hannover. Most of them were passing in rail 1 (see Figure 1). Various information like the type of train, number of wagons and other specifications were added based on the recorded videos of the train pass-by events. The 8th, the 13th, the 19th and the 22nd train were not rolling on the same rail as the others but on rail 3.

#	Type	Exact Train	No. Wagons	Rail No.	Remarks	Specification	Time
1	Long-distance	IC	5	1		Loco at the end, wagons not clearly seperated, Doppeldecker	15:53
2	Regional	Westfalenbahn	6	1		Doppeldecker	14:58
3	Freight	Cars	38	1			15:09
4	Freight	Mixed	27	1		container, tank and empty wagons	15:15
5	Freight	Tanks	15	1		different types of tanks	15:30
6	Regional	Westfalenbahn	6	1		Doppeldecker	15:33
7	Long-distance	IC	5	1		Doppeldecker	15:54
8	**Long-distance**	**ICE**	**14**	**3**		**on third rail, pretty slow**	**16:06**
9	Freight	Mixed	25	1		one), then empty, open roof and other wagons	16:13
10	Freight	Tanks	9	1			16:20
11	Regional	Westfalenbahn	6	1		Doppeldecker	16:25
12	Freight	open bulk freight (category F)	20	1			16:29
13	**Regional**	**enno**	**4**	**3**		**on third rail, pretty slow**	**16:39**
14	Long-distance	IC	5	1	honks (about 2 seconds before arriving)	Doppeldecker	16:53
15	Regional	Westfalenbahn	6	1		Doppeldecker	16:58
16	Long-distance	ICE	12	1		two coupled trains (first has 7 wagons, second 5)	17:04
17	Regional	enno	8	1		two coupled trains (4 and 4)	17:10
18	Regional	Westfalenbahn	6	1		Doppeldecker	17:25
19	**Regional**	**enno**	**4**	**3**	**rooster hearable 2 sec before train arrives**	**third rail**	**17:44**
20	Long-distance	IC	5	1		loco at the end, wagons not clearly seperated, Doppeldecker	17:56
21	Regional	Westfalenbahn	6	1	church bell	Doppeldecker	17:59
22	**Long-distance**	**ICE**	**14**	**3**		**on third rail, pretty slow**	**18:02**
23	Freight	Tanks	19	1			18:05
24	Regional	Westfalenbahn	6	1		Doppeldecker	18:25

Figure 3: Overview of the measured trains heading West (direction Braunschweig –> Hannover).

The table shown in Figure 4 present an overview of all the measured train pass-by events which were heading East - direction Hannover –> Braunschweig. Most of them were passing in rail 2 (see Figure 1) with exception of the 5th, the 8th, the 10th and the 13th trains which were not rolling on the same rail as the others but on rail 3.

#	Type	Exact Train	No. Wagons	Rail No.	Remarks	Specification	Time
1	Freight	Tanks	21	2			14:57
2	Long-distance	IC	5	2		Loco at the end	15:03
3	Regional	Westfalenbahn	6	2		Doppeldecker	15:44
4	Regional	Westfalenbahn	6	2		Doppeldecker	15:56
5	**Regional**	**enno**	**4**	**3**			**16:18**
6	Regional	Westfalenbahn	6	2	Voice at the beginning	Doppeldecker	16:34
7	Freight	Mixed	30	2		Empty flat and tank wagons (first empty, then tank, at the end empty again)	16:42
8	**Long-distance**	**IC**	**7**	**3**	**Voice at the beginning**		**16:56**
9	Long-distance	IC	5	2		Doppeldecker	17:02
10	**Regional**	**enno**	**4**	**3**			**17:16**
11	Freight	powder-shaped material	15	2		Staubgutwagen	17:21
12	Regional	Westfalenbahn	6	2		Doppeldecker	17:36
13	**Long-distance**	**ICE**	**8**	**3**			**17:54**
14	Freight	Mixed	28	2		Mostly tank and coiltransporter wagons	18:12
15	Freight	Mixed	44	2	at some points two trains at the same time	the whole time freight train with 16 container and 28 empty wagons, at the end also enno on rail 3	18:16
16	Freight	Empty	42	2		Flat wagons, some wagons in the middle were older than the others	18:21

Figure 4: Overview of the measured trains heading East (direction Hannover –> Braunschweig).

References

[1] Julian Christoffer Hoffmann. "Comparison of loudness models in the context of railway noise". In: *Student project, Techinsche Universität Braunschweig* (2020).

[2] Eisenbahn-Bundesamt. *Umgebungslärmkartierung an Schienenwegen von Eisenbahnen des Bundes*. 2017. URL: http://laermkartierung1.eisenbahn-bundesamt.de/mb3/app.php/application/eba (visited on 2020).

[3] DIN EN ISO 3095:2013. *Railway applications – Measurement of noise emitted by railbound vehicles*. Berlin: Deutsches Institut für Normung, 2013.

[4] ISO 532-1: 2017. *Acoustics — Methods for Calculating Loudness — Part 1: Zwicker Method*. Geneva, Switzerland: International Organization for Standardization, 2017.