MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Continuous acoustic monitoring of railroad network in the Czech Republic using smart city sensors

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ABSTRACT

Due to the high density of settlements in the Czech Republic, freight rail corridors are led through populated areas. Tracks are still dominated by noisy cars braked with metal brake blocks, which in the course of the passage cause several times higher noise than modern cars with non-metallic brakes. Although these are the technical parameters that determine the noise level of a train, it is not possible to find out of any registry proportion of obsolete noisy vehicles on tracks. The long-term objective of the project is to identify individual problematic trains in terms of noise. In cooperation with national railroad authority, a system has been developed that utilizes the CESVA TA120 measuring sensor network and is designed to provide to the railroad operator, in addition to all the train parameters that can be traced (carrier, time, weight, length, number of vehicles and axles, video recordings) other essential information about the passing train - sound exposure level of the train pass. The plan is to build a sensor network using the existing infrastructure so that a detailed overview of the noise level of each single freight train can be obtained.

Keywords: Railway noise, Monitoring, Sensors
I-INCE Classification of Subject Number: 71

1. INTRODUCTION

Main goal of this project is to obtain information about composition of freight railway transportation in the Czech Republic as far as noise is concerned. An analysis of measured data has been made using the Smartnoise platform. The data were obtained by several days continuous noise monitoring of freight trains on selected tracks in the Czech Republic, using CESVA TA120 smart city noise sensors. The project has been made in cooperation with Czech national railroad authority (SŽDC, s.o.).

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2. MOTIVATION AND DETAILED EXPLANATION OF THE ISSUE

In recent years, the share of so-called "silent" cars (cars with non-metallic brake blocks instead of the obsolete cast iron brake blocks) has been growing. Trains equipped with non-metallic brake blocks cause significantly lower noise levels when passing through. Due to the high density of settlements in the Czech Republic, freight rail corridors are led through populated areas and the noise limits are often exceeded. Therefore, it is important to focus on noise control of freight trains, which are dominant source of noise. However, it is not possible to determine of any register or operational records the share of these "silent" freight cars on the total number of freight cars, as well as the composition of the train in terms of the number of "noisy" and "silent" cars. Probably for this reason, there is often a zero (or very small) share of "silent" cars in acoustic studies modelling the future noise emission for the time horizon around 2020 or longer perspective. The parameters of freight trains are the most decisive about the extent of the noise control measures that need to be implemented, since "noisy" freight trains generates the most significant share of total noise emission. Although a significant reduction in railway noise is expected in the future, mainly due to the increase in the number of vehicles operated with non-metallic brake blocks (even with the assumption of higher freight traffic), a certain non-negligible part of the freight cars is equipped with non-metallic brake blocks already today. One of the aims of this project is to try to estimate the current share of "silent" freight cars. In order to do this, it was necessary to create a network of measuring points with autonomous sensors, which are capable of operating for long time periods.

3. CHOICE OF INSTRUMENTS

3.1 CESVA TA120 smart city sensor

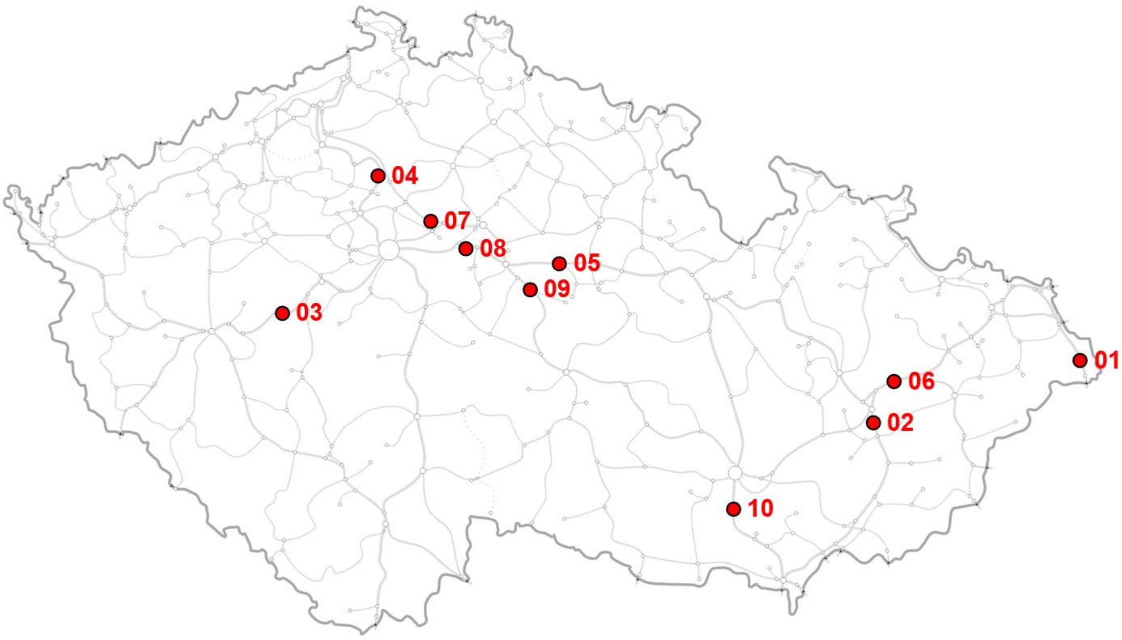
As optimal solution for above mentioned purposes, CESVA TA120 noise sensor was chosen. This sensor's original purpose is application in smart city solutions. However, it meets all the requirements of the project – it is fully autonomous, it doesn't need other external power source than connection to a public lighting (which was the only possible power source near measuring points) and it has a built-in GSM modem for wireless data transfer. It is a class 1 integrating sound level meter, which is determined to be used in exterior and it can be easily connected to existing infrastructure. The sensor measures L_{Aeq1s} [dB]. The data is stored in sensor buffer and is each 10 seconds sent to a remote server through modem. When there is a modem or mobile data network malfunction, the sensor stores the data and sends it as soon as it is back online.

3.2 SMARTNOISE platform

The Smartnoise platform was chosen to collect, analyse, visualize and archive data. It allows to make accurate continuous measurement of noise levels at a sampling frequency from 125 ms, measurement of L_{Aeq} or frequency analysis in the 1/1 and 1/3 octave band. The platform can host measurements networks from one point to a complex structure that counts hundreds of sensors across a single measurement network. On the basis of the data obtained, the platform performs processing and evaluation from one-shot sample to a set of data from annual measurements in tens of measuring points with sampling frequency of 1 second. The platform's analytics system allows data to be diagnosed based on long-term follow-up events or statistical data evaluation. For the purpose of visualization, Smartnoise offers a real-time representation of one or hundreds real-time measurements results, visualization of large data files with analytic notes, or the creation of third-party external display modules. All data can be exported to any desired format. Smartnoise Cloud offers fast integrated storage for large data files and their global instant availability through their own CDN network.

4. MEASURING POINTS

Monitoring was carried out at 10 measuring points. At each site was measured for at least 10 days. The measuring points were always placed next to main freight railway corridors. The microphone was positioned 5,0 m above the rails and 4,0 m from the axis of the closest track. Positions of the measuring points are indicated below on the map. The sensors were always connected to public lighting power source, which allows continuous operation. Example of positioning of the measuring point can be seen on picture 1.



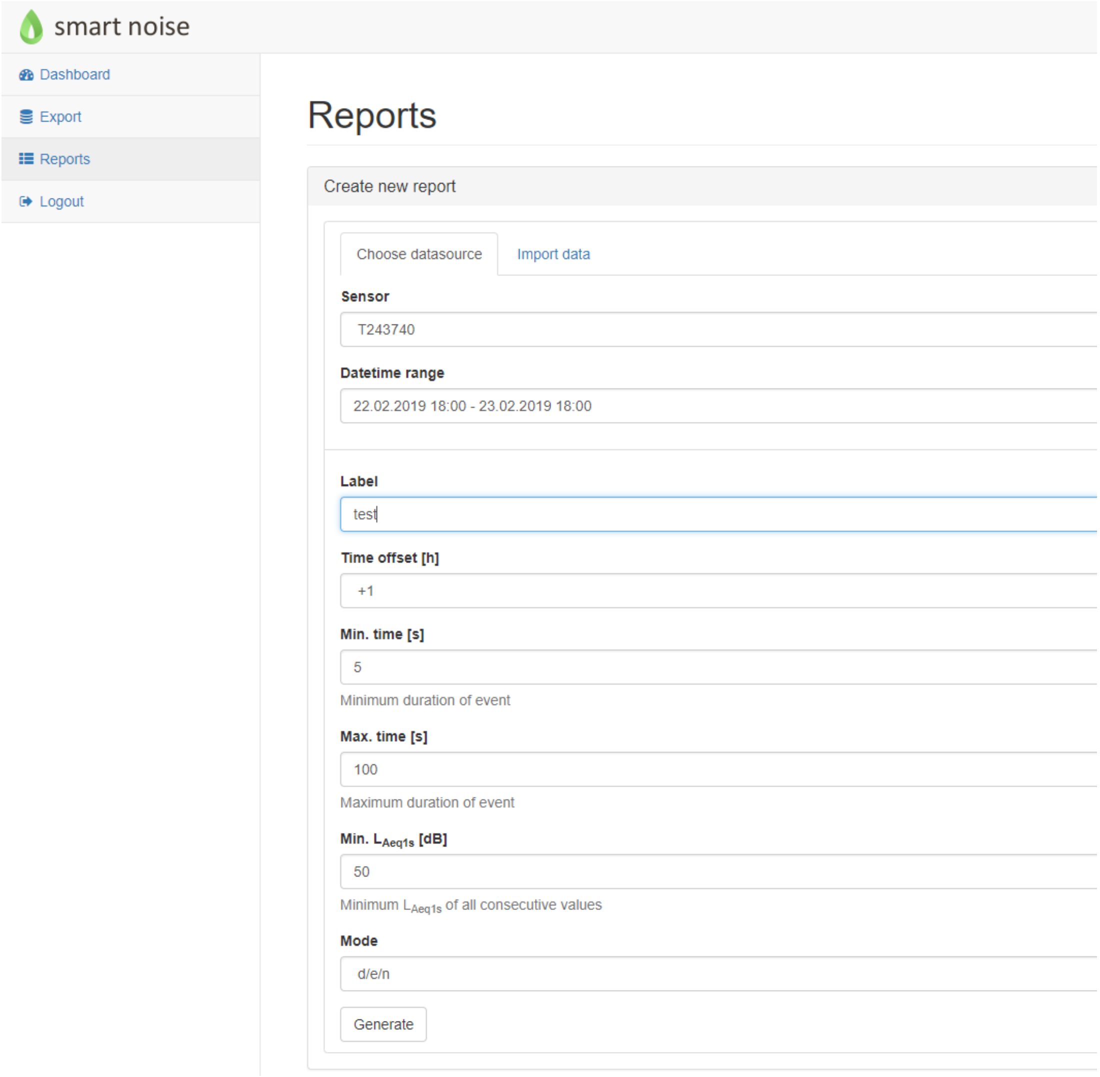
01 – Bocanovice
02 – Břest
03 – Cerhovice
04 – Cítov
05 – Lhota pod Přeloučí
06 – Osek nad Bečvou
07 – Otradovice
08 – Tatce
09 – Třebešice
10 – Vojkovice nad Svratkou

Picture 1 – Measuring point in Břest (02)

5. ANALYSIS

At each measuring point, continuous noise monitoring was carried out for at least 10 days. One second equivalent sound pressure levels (L_{Aeq1s}) were recorded. Since there is a lot of measured data, an automatic algorithm was created, which is capable of calculating sound exposure level (L_{AE}) of every single train pass, when entering appropriate input parameters. The parameters are set through Smartnoise web interface (see picture 2). These parameters are:

- Datetime range
- Time offset (in case the measured data are not synchronized with correct time, different timezone etc.)
- Minimum time (the shortest possible event) – this parameter is useful to eliminate unwanted noise, which is too short to be a train pass
- Maximum time (the longest possible event) – this setting is useful to eliminate unwanted noise, which is too long to be a train pass
- Minimum L_{Aeq1s} (threshold) – this parameter is useful to eliminate unwanted noise, which is too low to be a train pass



Picture 2 – Smartnoise interface

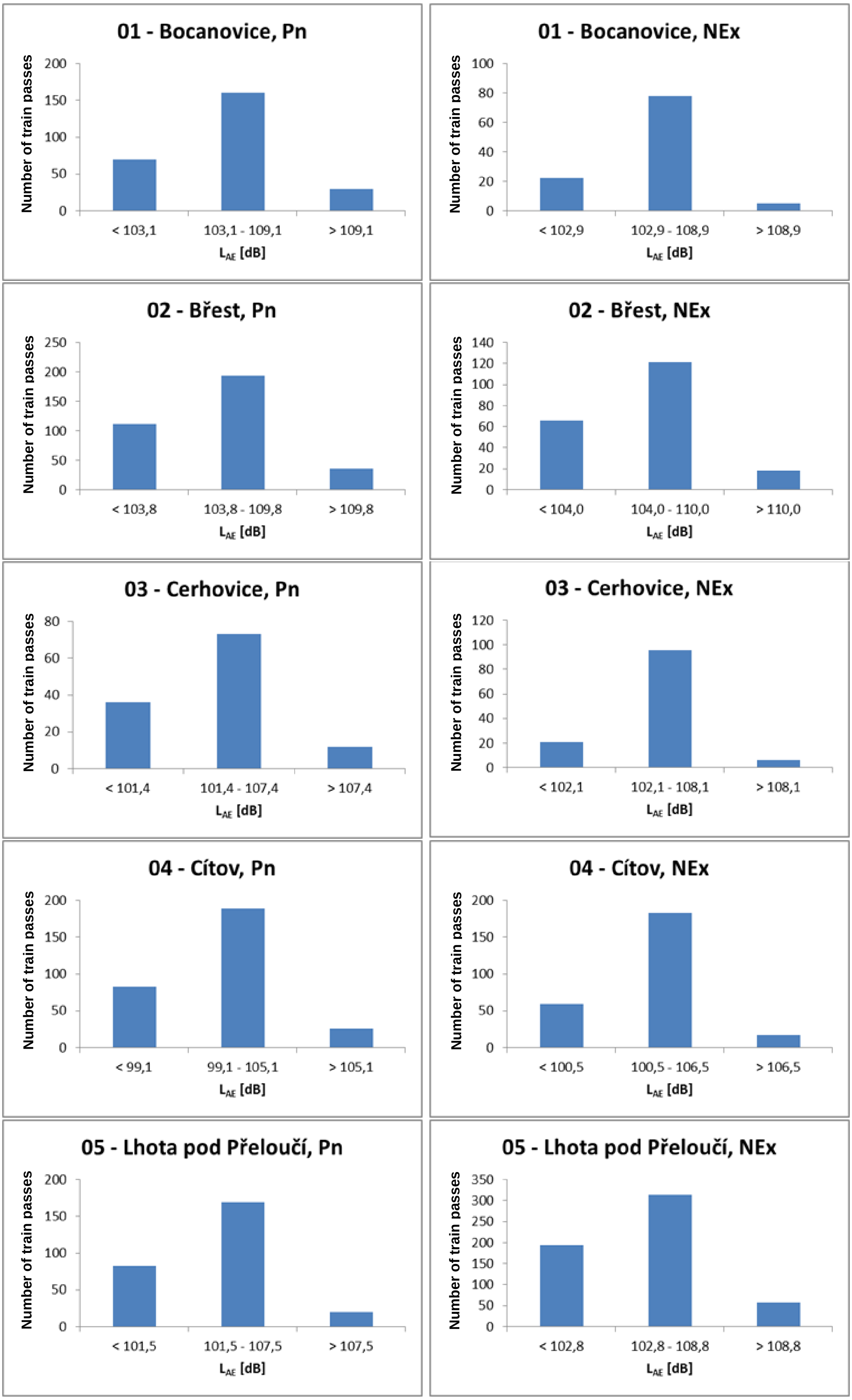
All these conditions have to be fulfilled simultaneously in order to create an event. The algorithm creates all events, which respond to set parameters. Sound exposure level (L_{AE}) was chosen for this purpose, because it contains acoustic energy of individual events and is always related to a time of 1 second, regardless of the duration of the event. Therefore, L_{AE} values are comparable, unlike L_{Aeq}, which cannot be compared with each other if the duration of events is different. Energetic average of L_{AE} values was calculated for 2 monitored train categories (category Pn – these are the freight trains used to transport cargo between the railway nodes, empty trains etc., category NEx – these are the freight trains that are used to transport priority cargo, usually international). Furthermore, the <average L_{AE} ± 3,0 dB> interval was specified. If the L_{AE} of a particular event is within this range, the event is marked as an average pass. Events outside this interval are marked as silent passes or noisy passes, depending on which side of the <average L_{AE} ± 3,0 dB> interval their L_{AE} value is located. Histograms below the table shows the proportion of average, silent and noisy passes in the measured data sets.

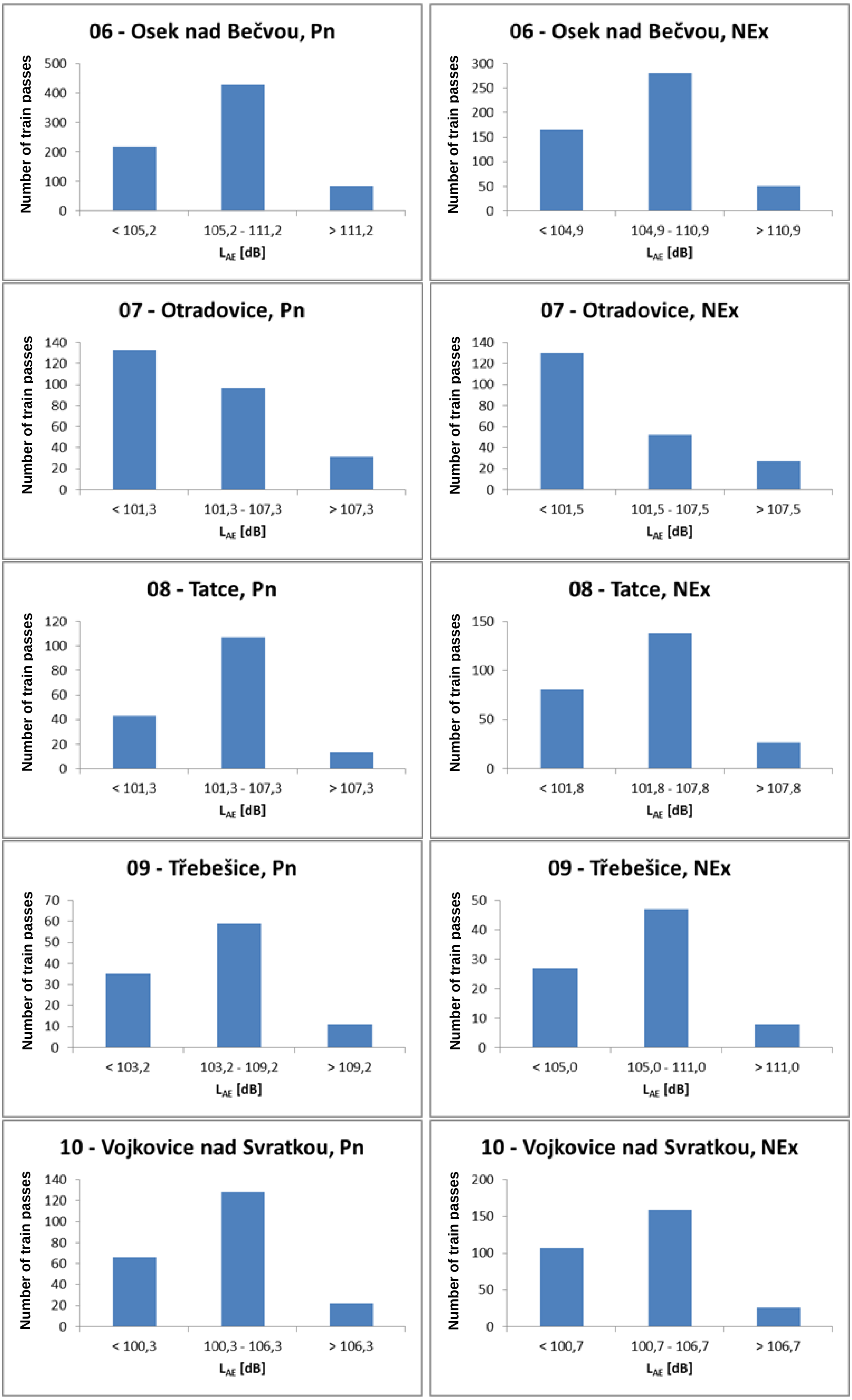
The noise level is predominantly influenced by the technical parameters of the individual cars of which the train is composed, in particular by the type of brakes, and it is less influenced by the number of cars (and associated parameters such as weight, length of the train, number of axles). In order to verify the hypothesis that the noise level does not depend significantly on the number of cars and the associated train parameters, an estimate of this dependence was made by calculating the Pearson correlation coefficient. The calculated coefficients indicate that there is no strong L_{AE} dependence on the train parameters, which confirms the hypothesis that the train noise is rather dependent on the technical parameters of the individual vehicles. In addition to the average L_{AE} and correlation coefficients, a sample standard deviation (σ) was also calculated for each set of data. From this value the noise variance of individual passes can be tentatively determined. The higher the value, the greater the variance. The analysis was performed separately for categories Pn and NEx, as well as for each measuring point. In following part there are the results in table form as well as histograms.

Table 1 - Results

Measuring point	*Train category*	*Total train passes measured*	*Energetic average L_{AE} [dB]*	*Sample standard deviation σ [dB]*	*Share [%]*		
					Silent passes	*Average passes*	*Noisy passes*
01 - Bocanovice	Pn	261	106,1	3,6	26,8	61,7	11,5
	NEx	105	105,9	3,3	21,0	74,3	4,8
02 - Břest	Pn	341	106,8	5,0	32,8	56,6	10,6
	NEx	205	107,0	5,2	32,2	59,0	8,8
03 - Cerhovice	Pn	121	104,4	4,1	29,8	60,3	9,9
	NEx	123	105,1	2,7	17,1	78,0	4,9
04 - Cítov	Pn	297	102,1	3,7	27,6	63,6	8,8
	NEx	259	103,5	3,3	22,8	70,7	6,6
05 - Lhota pod Přeloučí	Pn	271	104,5	4,2	30,3	62,4	7,4
	NEx	565	105,8	4,4	34,3	55,4	10,3
06 - Osek nad Bečvou	Pn	731	108,2	4,2	30,0	58,5	11,5
	NEx	494	107,9	4,1	33,2	56,7	10,1
07 - Otradovice	Pn	261	*104,3	*5,3	*51,0	*37,2	*11,9
	NEx	209	*104,5	*6,7	*62,2	*24,9	*12,9
08 - Tatce	Pn	163	104,3	3,5	26,4	65,6	8,0
	NEx	246	104,8	3,9	32,9	56,1	11,0
09 - Třebešice	Pn	105	106,2	4,7	33,3	56,2	10,5
	NEx	82	108,0	3,6	32,9	57,3	9,8
10 - Vojkovice nad Svratkou	Pn	216	103,3	4,1	30,6	59,3	10,2
	NEx	292	103,7	5,0	36,6	54,5	8,9

**distorted values, measuring was influenced by reduced speed limit*


01 - Bocanovice, Pn
Number of train passes
0
50
100
150
200
< 103,1
103,1 - 109,1
> 109,1
L_{AE} [dB]
01 - Bocanovice, NEx
Number of train passes
0
20
40
60
80
100
< 102,9
102,9 - 108,9
> 108,9
L_{AE} [dB]
02 - Břest, Pn
Number of train passes
0
50
100
150
200
250
< 103,8
103,8 - 109,8
> 109,8
L_{AE} [dB]
02 - Břest, NEx
Number of train passes
0
20
40
60
80
100
120
140
< 104,0
104,0 - 110,0
> 110,0
L_{AE} [dB]
03 - Cerhovice, Pn
Number of train passes
0
20
40
60
80
< 101,4
101,4 - 107,4
> 107,4
L_{AE} [dB]
03 - Cerhovice, NEx
Number of train passes
0
20
40
60
80
100
120
< 102,1
102,1 - 108,1
> 108,1
L_{AE} [dB]
04 - Cítov, Pn
Number of train passes
0
50
100
150
200
< 99,1
99,1 - 105,1
> 105,1
L_{AE} [dB]
04 - Cítov, NEx
Number of train passes
0
50
100
150
200
< 100,5
100,5 - 106,5
> 106,5
L_{AE} [dB]
05 - Lhota pod Přeloučí, Pn
Number of train passes
0
50
100
150
200
< 101,5
101,5 - 107,5
> 107,5
L_{AE} [dB]
05 - Lhota pod Přeloučí, NEx
Number of train passes
0
50
100
150
200
250
300
350
< 102,8
102,8 - 108,8
> 108,8
L_{AE} [dB]


06 - Osek nad Bečvou, Pn
Number of train passes
500
400
300
200
100
0
< 105,2
105,2 - 111,2
> 111,2
L_{AE} [dB]
06 - Osek nad Bečvou, NEx
Number of train passes
300
250
200
150
100
50
0
< 104,9
104,9 - 110,9
> 110,9
L_{AE} [dB]
07 - Otradovice, Pn
Number of train passes
140
120
100
80
60
40
20
0
< 101,3
101,3 - 107,3
> 107,3
L_{AE} [dB]
07 - Otradovice, NEx
Number of train passes
140
120
100
80
60
40
20
0
< 101,5
101,5 - 107,5
> 107,5
L_{AE} [dB]
08 - Tatce, Pn
Number of train passes
120
100
80
60
40
20
0
< 101,3
101,3 - 107,3
> 107,3
L_{AE} [dB]
08 - Tatce, NEx
Number of train passes
150
100
50
0
< 101,8
101,8 - 107,8
> 107,8
L_{AE} [dB]
09 - Třebešice, Pn
Number of train passes
70
60
50
40
30
20
10
0
< 103,2
103,2 - 109,2
> 109,2
L_{AE} [dB]
09 - Třebešice, NEx
Number of train passes
50
40
30
20
10
0
< 105,0
105,0 - 111,0
> 111,0
L_{AE} [dB]
10 - Vojkovice nad Svratkou, Pn
Number of train passes
140
120
100
80
60
40
20
0
< 100,3
100,3 - 106,3
> 106,3
L_{AE} [dB]
10 - Vojkovice nad Svratkou, NEx
Number of train passes
200
150
100
50
0
< 100,7
100,7 - 106,7
> 106,7
L_{AE} [dB]

5. CONCLUSIONS

The idea was to make a complex analysis of data obtained by monitoring of freight railway noise by smart city sensors. The project has proven, that with appropriately chosen instruments, precisely set input parameters, a fast evaluation of even a large amount of data can be done. An estimate of share of "silent" trains was made. When considering the measured data as a starting position, we can easily observe the proportion of "silent" trains changing in time. With a noise sensor network, such as the one used in this project, which is connected to existing monitoring infrastructure (video monitoring, train detection systems, etc.), which is already capable of recognizing individual trains, it is easy to mark specific trains as extremely noise, or particularly silent. The noise monitoring can later be useful to control railway noise.

6. ACKNOWLEDGEMENTS

We acknowledge gratefully the SŽDC, s.o. for cooperation on this project.

7. REFERENCES

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