Construction and urban noise: automatic assessment of noise monitoring results

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Summary

In many cases legal noise limits should be met at dwellings due to the noise of construction projects. Noise levels in urban areas are caused by several different noise sources. An analysis algorithm has been developed to indicate whether the noise is due to construction activities or is produced by urban noise sources (e.g. road and railway traffic noise). This algorithm consists of characterization of the noise based on spectral differences and the dynamics of the noise. The output of the algorithm is the so called 'Construction Noise Index', classifying the characteristics of construction noise on a scale of 0 to 100. The index gives an indication whether the measured noise is produced by construction work or is due to other urban noise sources. This way extensive manual analysis of measurement data can be avoided. The Construction Noise Index is developed and used for noise monitoring near multiple construction sites in an urban area where the largest European urban redevelopment projects are done up until 2030. **PACS no. 43.50.+y, 43.60.+d**

1. Introduction

With the rise of noise monitoring facilities, continuous measurements on multiple sites are becoming more common. New challenges arise in the interpretation of the measured sound pressure levels. Normally the sound pressure levels due to one specific noise source of group of sources need to be determined. Manually separating the sound pressure levels of the specific noise source and disturbing noise of other noise sources by audible determination is hard especially with long term noise monitoring. Therefore analysis algorithms could help in separating the relevant and irrelevant parts of large datasets. Such challenges arise for example with monitoring of music (outdoor) events, industrial noise or wind turbine noise and construction noise. This paper focuses on a specific situation in an urban area where the noise due to multiple construction projects at dwellings is measured and analyzed with automatic assessment of the noise as construction noise or urban noise.

2. Situation

In the inner city of Utrecht the area surrounding the Central Station is redeveloped where multiple construction works are done simultaneously (see figure 1, the square dots represent all large construction projects). Because of the size of the redevelopment projects and multiple projects are done at the same time, the impact of the noise due to these construction works at dwellings is substantial. In the centre of this area three large apartment blocks are situated. The apartment dwellers are surrounded by the construction projects and exposed to construction noise for many years.

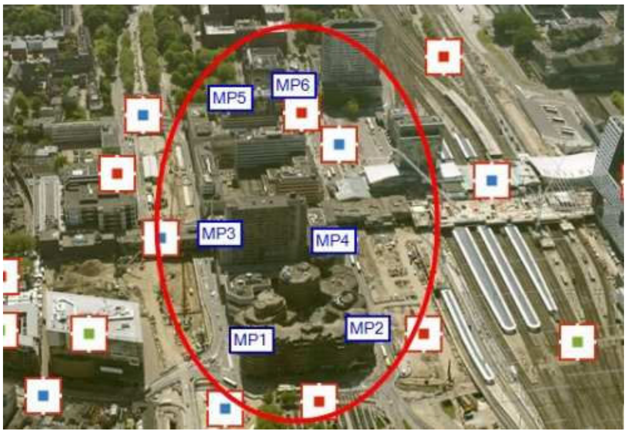

Figure 1. Situation City of Utrecht, area near Central Station, with six noise monitoring positions

Legal limits for construction noise are imposed per project. In The Netherlands legal limits have been set for construction work ranging from 60 to 80 dB(A) equivalent sound pressure level at the facade of a dwelling during working days in the day period (07.00h tot 19.00h)[1]. If the sound pressure levels are higher than 60 dB(A) the total permitted working days are limited.

With the noise limits per single project, the impact and possible annoyance at the living areas is supposed to be separated per project but is in practice caused by the total amount of noise at the dwellings. For this situation there is chosen to assess the total sum of construction noise to situation dependent noise limits regardless of the origin (which project) of the noise.

In this context the analysis algorithm is developed and used as a supportive tool in assessment of the noise afterwards. Because of the relatively high urban noise near the considered dwellings and the several projects done at the same time, the analysis algorithm is not used for law enforcement purposes.

3. Characterization of urban and construction noise

Urban noise consists of many noise sources, both continuous (background) and fluctuating (foreground) noise. The main urban noise sources are road traffic (both nearby and faraway roads) and railway. Furthermore several incidental events contribute to the urban noise profile, for instance sirens, human voices, speeding motorcycles, et cetera.

In general (loud) construction noise is mainly produced by:

- Heavy (diesel) engines, hydraulic pumps;
- Hammering or vibrational pile driving for laying foundations;
- Hand operated (electrical) machines like saws, drills, et cetera.

Construction noise can in general be characterized as follows:

- Due to the diesel engines it has a relatively low-frequent spectrum;
  and/or
- Due to hammering and drilling activities it has a relatively high dynamic sound pressure level.

In other words the C-weighted sound pressure levels are substantially higher than the A-weighted sound pressure levels and/or the statistical sound pressure levels L_{10} and L_{95} are distinguished from each other.

Although urban and construction noise are both by nature alternating, construction noise is more or less distinctive by the above stated parameters.

4. Construction Noise Index

The algorithm should analyze the sound measurement data and qualify portions of the data based on the distinctive parameters with an index (for instance 0..100). A 5 minute analysis interval is chosen, mainly to match with possible perceived annoyance due to a ‘noise event’ caused by construction work. A ‘noise event’ due to construction work may only be perceived as annoyance if the time the disturbance takes place is substantial. It is debatable what time interval fits best with the perceived annoyance. For this situation a 5 minute scale appears to be suitable: it is shorter than most ‘noise events’ due to construction noise so it detects and expresses the averaged maximum sound pressure levels, without overestimate short peaks. On the other hand is is short enough to avoid over-averaging the sound pressure levels in an equivalent sound pressure level with a duration much longer than the ‘noise event’.

The relatively low frequent spectrum of construction noise is expressed in equation

$$\mathrm{L_{Ceq,5min}} - \mathrm{L_{Aeq,5min}} - 10 \qquad (1)$$

For this situation the average difference between the C-weighted and A-weighted urban (background) noise is 10 dB. Therefore a 10 dB correction is made to fit for the urban noise average difference of 10 dB between C-weighted and A-weighted broad band noise (based on long term measurements in this area).

The dynamics of the noise is expressed in equation

$$\log\left({L_{A95}}/{L_{A10}}\right) \qquad (2)$$

Construction noise is only relevant if it exceeds the background noise levels. Therefore a threshold level is incorporated in the index; only above the threshold level the analysis algorithm comes into effect and evaluates this registered noise data. These threshold levels are chosen specific per measurement position, based on the average urban noise levels already present and depending on the period of the day (day, evening or night). The threshold levels are based on measurements during a relatively long period that no construction work was done.

Furthermore several constants are added for scaling purposes, so the index has a bandwidth of approximately 0 to 100.

The Construction Noise Index (CNI) is calculated as follows:

$$CNI = 2.5 \times (eq.(1)) - 350 \times (eq.(2)) - 6$$

with the following constraints:
If equation (1) or equation (2) < 0 then CNI = 0
If $\mathrm{L_{Aeq,5min}} < Threshold$ level then CNI = 0

The Construction Noise Index can be used as follows:

- CNI = 0: There is no indication that the noise level was due to construction noise.
- CNI = 100: The noise has the same characteristic as construction noise so it is very likely that the noise is totally due to construction work.
- 0 < CNO < 100: The noise has some similarity with the characteristics of construction noise. So it is possible that the noise is due to construction work.

5. Implementation

In the area near the Central Station of Utrecht three apartment buildings exist (see figure 1, MP1 to MP6, MP=Measurement Position). At every corner of the buildings a monitoring system has been placed. Every system measures the noise in broadband values L_{Aeq}, L_{Ceq} and L_{Amax}. The measured sound pressure levels are uploaded by a wireless network to the internet and stored in a database with 16 values per position per second (with a ‘fast’ integration time). The audio signal is recorded as well and streamed to an internet server. Via a web portal the real time and historical measurement data of all six positions can be viewed and listened to. In addition to the raw measurement data the analysis algorithm is implemented at the server whereby every time a historical graph is viewed the Construction Noise Index is calculated instantaneously per 5 minute portion of the historical data. Naturally, for this a statistical operation of the historical data is needed to calculate the L_{10} and L_{95} statistical sound pressure levels per 5 minutes. Such an analysis can only be done with enough processing power on the server, whereby the benefits of processing power for fast repetitive tasks is used.

6. Results

In the following figures measurements are presented along with a calculated CNI during several specific construction work activities.

In figure 2 the measured $L_{Aeq,5min}$ is given, together with the calculated CNI. In the day period several moments vibratory pile driving activities occur with corresponding sound pressure levels of more than 80 dB(A) at the sound measurement position. Vibratory pile driving can be characterized as both relatively low frequent ($L_{Ceq} >> L_{Aeq}$, see formula 1) and relatively dynamic ($L_{10} >> L_{95}$, see formula 2). As a consequence the calculated CNI is in a range 40 to 80.

During the measurements given in figure 3 power floating occurs in the night period with corresponding sound pressure levels at the measurement position of 60 to 62 dB(A) (5 minute averaged). Power floating noise has neither a very dominant low frequency spectrum nor is highly dynamic. As a consequence the calculated CNI is limited (40 to 50) but construction noise is still indicated. At several moments that night the calculated CNI is zero while power floating activities have taken place (period between 23.00 and 00.30 hour). This can be explained by the threshold level at this measurement position of 60 dB(A). If the $L_{Aeq,5min}$ is lower than 60 dB(A), then the CNI is zero (see for the constraints in chapter 4).

At figure 4 a steady noise level is presented during the night period of 60 to 61 dB(A). During this night pouring concrete has been done with concrete mixers, concrete pumps, cranes and poker vibrators. Due to the heavy diesel engines the noise is relatively low frequent ($L_{Ceq} >> L_{Aeq}$) but not very dynamic ($L_{10} > L_{95}$). As a consequence a CNI is calculated in a range of 0 to 50.

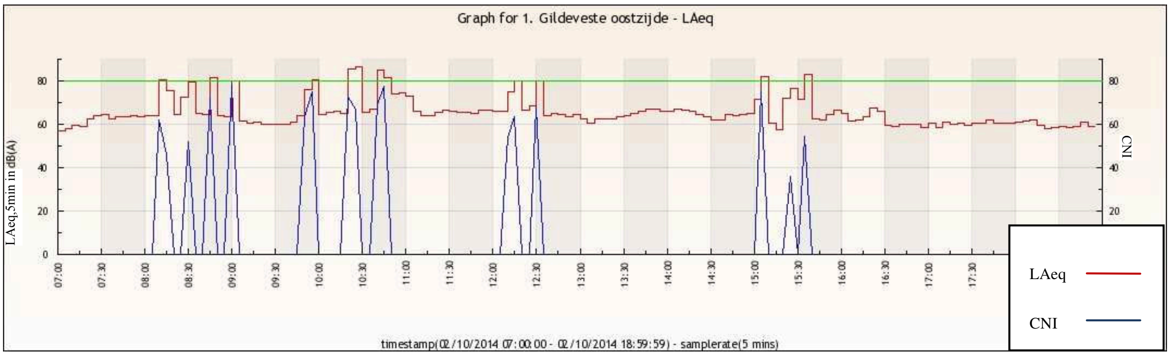

Figure 2. Measured $L_{Aeq,5min}$ in dB(A) and calculated CNI during vibratory pile driving (day period)

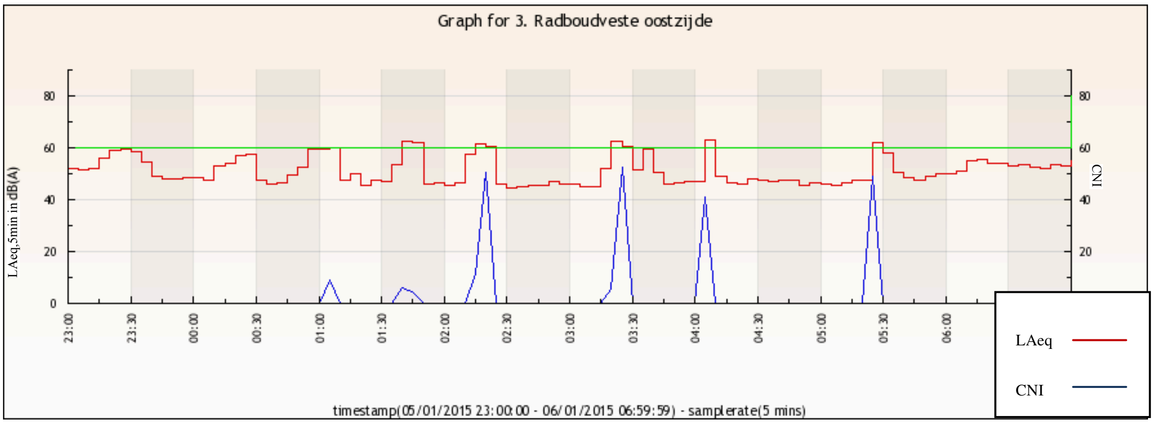

Figure 3. Measured $L_{Aeq,5min}$ in dB(A) and calculated CNI during power floating (night period)

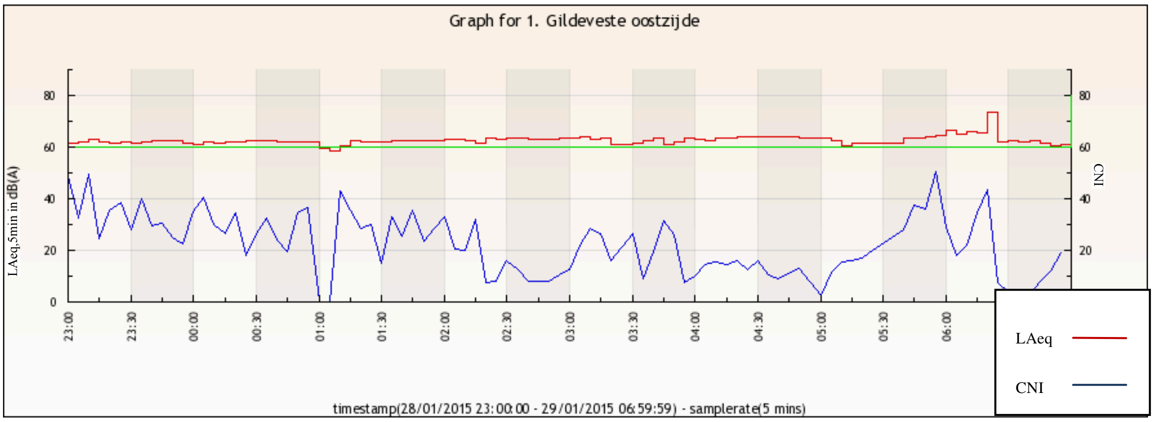

Figure 4. Measured $L_{Aeq,5min}$ in dB(A) and calculated CNI during concrete pouring (night period)

7. Evaluation

From figures 2 to 4 is concluded that using a indicator based on frequency division and dynamics calculation a useful tool has been made. At the total processed data roughly 2% to 3% is indicated as relevant construction noise. The day period, where most of the construction work is done, is mostly neglected by the algorithm because of the relatively high present urban noise and corresponding high threshold level. This part of the construction is also less relevant for the noise nuisance.

It is found that within the urban noise there are several incidents where a calculated CNI gives a score while it is not construction work. Especially sirens and freight trains, and moments with storms are wrongly scored with a relevant CNI. Further optimization of the CNI could avoid these faulty indications. For instance by implementing an additional parameter for slowly rising high level noise events. Further research and development on this part of the algorithm is needed.

In the algorithm a fixed threshold level is implemented depending on the average background noise per measurement position. An improvement could be made with a threshold level depending on the actual measured background noise, for instance based on a L_{95} during the previous few hours.

Such a noise indicator (with another algorithm) could be used at other situations as well, for instance at outdoor music events where one operator evaluates several online noise monitoring positions whereby an indication of the noise can assist in assessment of the noise data.

8. Conclusions

Assessing large data sets by calculating an index based on specific noise profiles prove to be helpful. The Construction Noise Index can be calculated with only dB(A) and dB(C) broad band values, so relative simple sound level meters can be used. The Construction Noise Index is therefore a helpful tool in indicating relevant 'construction noise events' during long term noise monitoring whereby manual data processing can be done more efficiently.

A 100% certain division between construction noise and urban noise however, is yet not possible with the used tools. Further research could be done in optimizing the analysis tool, for instance by expanding the analysis calculation model with railway noise detection and more sophisticated implementation of the threshold values, for instance depending on the actual background noise present at the measurement position.

References

[1] Dutch law for buildings 'Bouwbesluit 2012', article 8.3 (see wetten.overheid.nl)