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NOISE OF HIGH SPEED TRAINS IN THE NETHERLANDS: AN EXPLORATION

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1 INTRODUCTION

The Netherlands, a country with a total area of roughly 41.500 km^2, has over 2800 km of railways. This amounts to 67.4 meters of railways for each square kilometer, which is more than for instance France (27.2 m/km^2), but less than Belgium (114.6 m/km^2). So the Netherlands have a relatively dense railway network, yet these were all low speed. High speed railways were for long not considered necessary, as the Netherlands is a small country.

In 1998 it was decided that high speed railways (HSR) line should be constructed, connecting it with the trans-European high speed Network (TEN-T). The first HSR line to be constructed was the “HSL-zuid”, a 125 km long railway between the Netherlands and Belgium. Construction started in 2000, and in September 2009 the first commercial high speed trains started service. At first this was a shuttle service between Amsterdam and Rotterdam, and in December 2009 the Thalys started using the HSL-zuid, resulting in a travel time of 3 hours 13 minutes from Amsterdam to Paris. The shuttle service is called “Fyra”[1], and currently consists of one train per hour. At this moment the train consists of conventional intercity carriages, pulled by a TRAXX locomotive, and has a maximum speed of 160 km/h. An example of such a train is shown in Figure 1.

Figure 1: A “Fyra” train, with a Bombardier TRAXX locomotive.

It is expected that in December 2010, these trains will be replaced with a V250 trains by AnseldoBreda, which have a maximum speed of 250 km/h.

The track system used for the most part of the HSL-zuid was Rheda 2000, a ballastless system where the sleepers are integrated in the concrete foundation[2]. An example is shown in Figure 2.

Figure 2: A RHEDA 2000 track

A schematic representation of the line between Amsterdam and Rotterdam is shown in Figure 3.

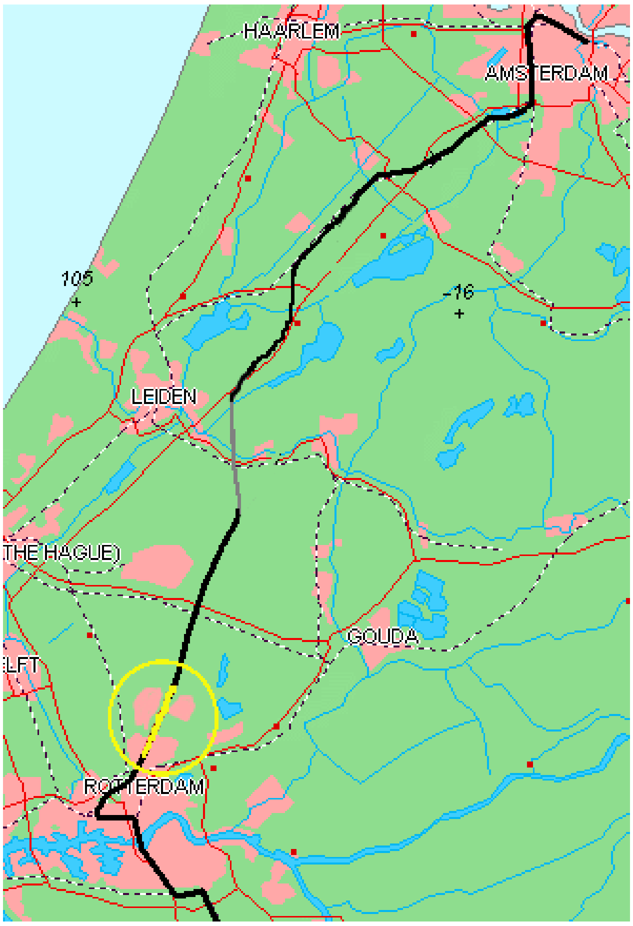

Figure 3: Representation of the HSL-zuid between Amsterdam and Rotterdam, indicated by the black line. The grey part indicates a tunnel, and the yellow line is where the open tunnel is located.

The line itself consists of several different engineering structures, such as:[3]

- Several railway viaducts over motorways and other railways
- A bored tunnel in the "Groene Hart"
- A half-sunken open tunnel near the municipality of Lansingerland (north of Rotterdam)

Since the start of the operations, complaints over the noise produced by the high speed trains emerged as well. Most of these complaints originated in the Lansingerland region, where the trains travel through a half-open tunnel[4]. In response, the Dutch track manager ProRail commissioned TNO to perform exploratory measurements near the HSL line, in order to examine if the measured noise levels are higher than the expected noise levels based on calculation models. [5]

RIVM carries out a monitoring program that is commissioned by the Dutch Ministry of Spatial Planning, Housing and the Environment (VROM). As part of this program a first assessment of the current noise impact of the HSL was made. Using the noise emission data as measured by TNO, the National Institute for Public Health and the Environment (RIVM) set up a noise map. The aim was to assess the exposure of the population and gain insight into the causes for complaints. Both average noise levels (L_{den}) and maximum noise levels (L_{max}) were determined on nearby dwellings and evaluated. This paper compares the actual (measured) noise emissions with noise emissions as available in the Dutch standard calculation model (ASWIN), evaluates exposure levels, and looks into the future situation around the track.

2 MEASURED EMISSIONS

In September 2009, TNO carried out noise measurements at four locations near the HSL line, of which two were located in the aforementioned Lansingerland region. The measured levels were sound exposure levels (*SEL*) and can be converted to normalized emission levels (E^*). E* is the noise emission caused by one train compartment per hour and is determined from the measured SEL according to:

$$E^* = SEL_{measured} - 10\log(n) - 10\log(3600) + \Sigma D + 10\log(a) \qquad (1)$$

Here, n is the number of compartments on the train from which the noise was measured, and 10log(n) and 10log(3600) convert the *SEL* to an emission E^* valid for a traffic density of one compartment per hour. ΣD is a correction term for ground and air attenuation, which is around 1 dB, and a is the distance from the train to the microphone.

When the number of compartments per train n and the number of trains per hour Q are known, the total noise emission E , as used in the Dutch standard calculation method (ASWIN), can be obtained from the normalized emission E^* using:

$$E = E^* + 10\log(nQ) \qquad (2)$$

Using these two equations, the *SEL* values from the TNO measurements were converted to actual emission levels. These levels were compared with the Dutch Standard calculation method for railway traffic noise (ASWIN) [6], which provides the emission levels for nine train categories used in the Netherlands. For instance, according to the calculation method, the TRAXX train with conventional intercity carriages traveling at a speed of 160 km/h falls in category 8 and was expected to have a normalized emission level E^* = 61 dB [†]. However, after converting the *SEL*- levels measured by TNO, a line-averaged normalized emission of E^* = 71 dB is found, with a peak of E^* = 74 dB in the Lansingerland region. Based on the timetable from December 2009, which consists of 3 trains per hour, and 8 compartments per train emission levels for the TRAXX

[†] The vehicle category used to calculate the emission level was category 8 (intercity trains) instead of category 9 (high speed trains).

trains can be determined. This results in a total average noise emission level of 85 dB and for the Lansingerland a total noise emission of 88 dB

In addition, in September 2009, RIVM also carried out some exploratory measurements at two sites, the first at the north end of the bored tunnel near Hoogmade, and the second near the half-sunken open tunnel near Lansingerland. Two pictures of the railway track near the measurement sites are shown in Figure 4. Here, the difference between the railway tracks on ground level and in the open tunnel can be seen.

(a) **(b)**

Figure 4: The two locations where RIVM performed exploratory measurements, Hoogmade (a) and Lansingerland (b).

At each site, the Sound Energy Level was measured of two passing trains, one in each direction. These measured *SEL* values can be converted to emission levels using equations 1 and 2. The results are shown in Table 1, where the directions are indicated by Rotterdam – Amsterdam (Ro-Am) and vice versa.

Table 1: Results of the exploratory measurements performed by RIVM on September 2009.

site	direction	*SEL* (dB)	*a* (m)	*n*	*E** (dB)	*E* (dB)
a Hoogmade	Ro-Am	99.4	17	8	68.1	81.9
a Hoogmade	Am-Ro	104.4	17	8	73.1	86.9
b Lansglnd.	Ro-Am	98.3	15	8	66.5	80.3
b Lansglnd.	Am-Ro	108.7	12	8	75.9	89.7

These are only indicative results, as only one measurement for each site and direction was done. However, they are in line with the conclusion that the measured noise emission levels are much higher than the levels predicted by the standard calculation method.

3 NOISE MAPS

Using the noise emissions as measured by TNO outlined in the previous paragraph, a noise map was set up according to the Dutch Standard calculation Method for railway traffic noise[6]. The noise levels are indicated by the daily averaged noise level L_{den}, which is determined from the emission E_i calculated according to:

$$L_{den,i} = E_i - A_{Geo,i} - A_{Air,i} - A_{Ground,i} - A_{Barrier,i} - C_{Meteo} - 58.6 \tag{3}$$

in which the L_{den} is the noise level at the observation point. *E* is the noise emission of the source and the '*A*'-terms denote the attenuation from source to receiver due to geometric spreading (A_{Geo}), air absorption (A_{air}), ground impedance (A_{ground}) and Noise Barriers. The index *i* runs over eight octave band numbers, with centre frequencies ranging from 63 Hz up to 8 kHz. C_{Meteo} is a frequency independent meteorological correction accounting for varying wind directions and temperature gradients. The constant of 58.6 dB is a correction for dimension changes. A noise map showing the L_{den} levels in Lansingerland is shown in Figure 5.

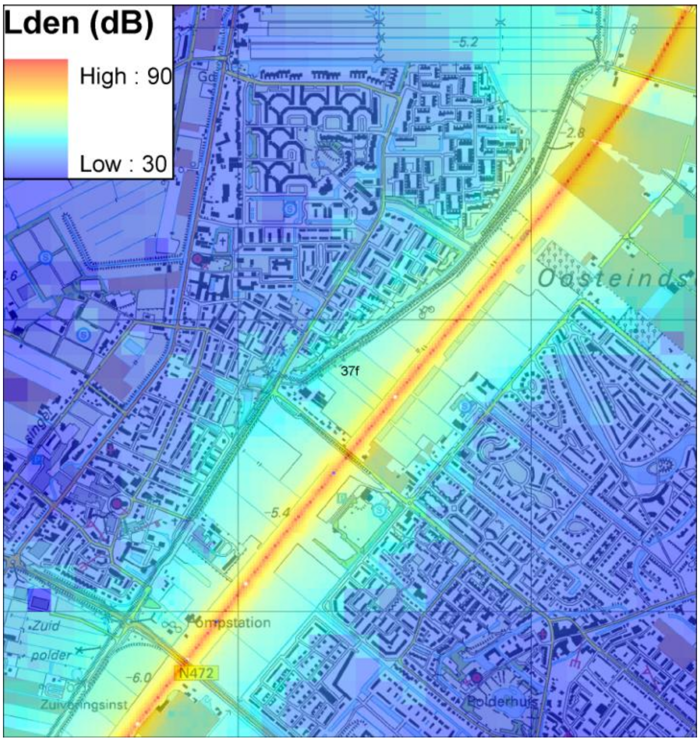

Figure 5: L_{den} levels in the Lansingerland municipality

Apart from L_{den} levels, which by definition are averaged over 1 year, also the L_{max} levels were determined. This was done, because complaints particularly seem to emerge from high levels during train passage, and L_{den} levels remain relatively low, as only two trains per hour are passing by. To first approximation, for a line source L_{max} values are related to L_{Aeq} values according to:

$$L_{\max} = L_{Aeq} - 10\log\left(\frac{\pi a q}{v}\right) \tag{4}$$

with *q* the number of trains per second. Estimated L_{max} levels are shown in Figure 6 for the same area as Figure 5.

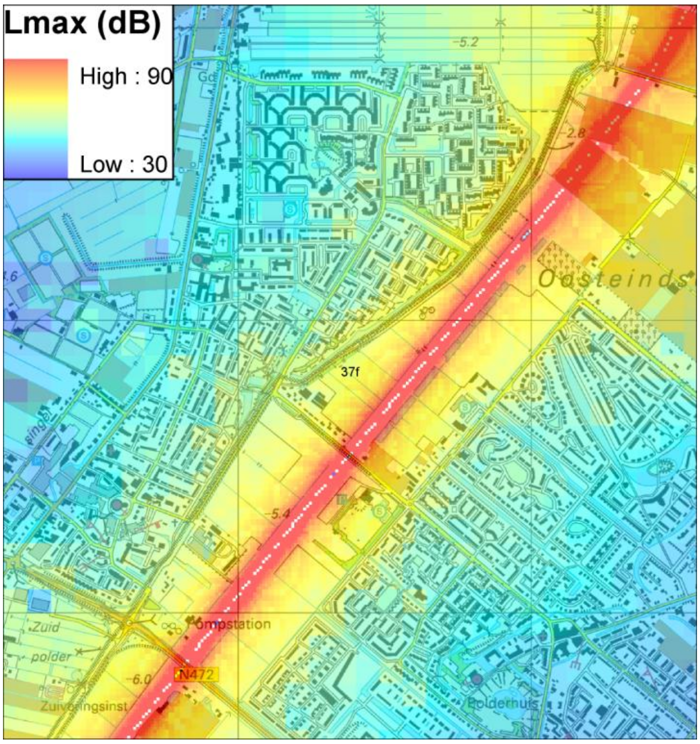

Figure 6: L_{max} levels in the Lansingerland municipality.

4 CONSEQUENCES FOR THE ENVIRONMENT

From Figure 5 it can be seen that L_{den} levels in the surrounding dwellings are fairly low, with most dwellings exposed to L_{den} levels lower than 60 dB. This is due to the fact that L_{den} is a daily averaged noise indicator, and the current service of the trains (daytime 3 per hour, 0 in nighttime) leads to low average noise levels. In contrast, the L_{max} levels the dwellings are exposed to are much higher, at some places even 20 dB higher than the L_{den} level.

For the entire HSR line, the impact of the noise levels on the surrounding dwellings were examined using GIS data containing the locations of dwellings in the Netherlands. The cumulative amount of dwellings exposed to certain L_{den} and L_{max} levels was determined, and the results are shown in Figure 7.

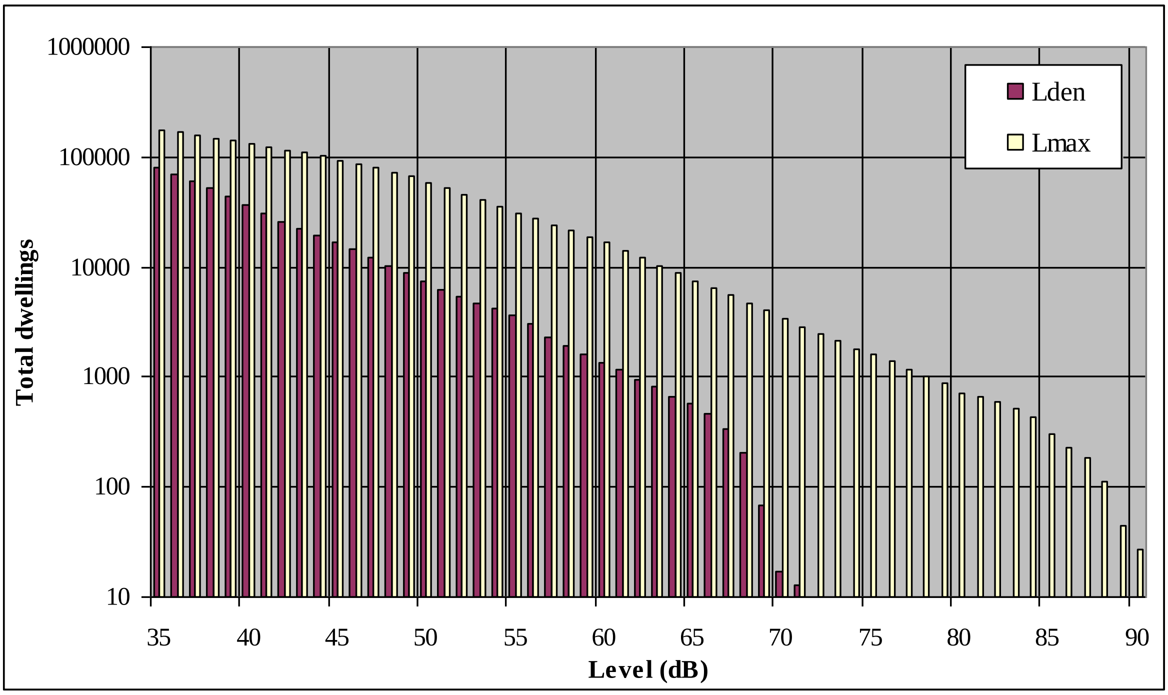

Figure 7: The number of dwellings exposed to L_{den} and L_{max} levels due to high speed trains.

Here, the cumulative amount of dwellings exposed to levels exceeding the value given in the horizontal axis. For instance, around 100 dwellings are exposed to L_{den} levels of 69 dB and lower, whereas several 1000s are exposed to L_{max} levels of 69 dB. No dwellings are expected to have L_{den} levels exceeding 81 dB, but L_{max} levels of over 90 dB at dwellings occur.

For Lansingerland specifically, almost 1000 persons are exposed to L_{max} levels over 65 dB, which probably the main cause for many complaints. Although L_{den} values are relatively low at the moment, they will increase once more trains will be taken into service. In addition to current high L_{max} values this could in future also result in high average values. In view of many complaints now the problem could dramatically increase, and continuing the use current stock with high L_{max} values is no real option.

5 CAUSES AND OPTIONS FOR IMPROVEMENT

Using noise annoyance relationships for railway traffic noise according to Miedema[7] the number of highly annoyed people was estimated using the L_{den} histogram shown in Figure 5. This results in a total of 1000 highly annoyed people and specifically for Lansingerland around 200 people highly annoyed (0.5 % of the total population of Lansingerland). These are fairly low numbers, and can not explain the severe public complaints against the noise due to the high speed trains. The obvious reason is that the annoyance cannot not be linked to L_{den} levels, but probably is caused by the high L_{max} values during the train passages. Unfortunately, no dose response relations that relate L_{max} values to complaints or annoyance are available.

High L_{max} values stem from the high noise emission levels E, which were observed to be unusually large as compared to category 8 noise emissions in the standard Dutch calculation method. At this moment several causes for these high emission levels were detected and considered, of which an overview is given below:

- The combination of the current TRAXX/intercity trains and the RHEDA 2000 track system causes much higher noise levels than expected. This was already concluded in an earlier TNO research[8]. Noise control measures to lower the noise emission levels are to reduce the rail roughness, add vibration absorption to the tracks and to reprofile the wheels of the intercity carriages. The current TRAXX uses an obsolete braking system causing high wheel roughness that is copied into the rail surface. It is expected that after the TRAXX trains will be replaced permanently with the envisaged V250 trains, wheel and rail roughness will be reduced and so noise emission levels will decrease significantly.

- In the Lansingerland region, the train travels through a half-sunken open tunnel, which is a massive concrete structure with noise barriers placed on top of it, as shown in Figure 4(b). Additional noise barriers could provide some cover to the noise produced by the trains, but perhaps the noise reflection properties of the concrete structure was not taken into account. Reflections between the barrier and the train that reduce the barrier effect may be suppressed by applying absorption on the inner side of the barriers and/or on concrete surfaces of the open tunnel
- However, another possible cause for the noise emission of the TRAXX trains is the absence of ballast and the tight connection of the rails to the concrete slab. Subsequently vibration energy from the rails can be transferred to the entire concrete structure which converts and radiates the vibration energy as noise. If this is the main cause for current high emissions, reducing noise emission by higher barriers or absorption could be problematical. The best option in this case seems to allow only disc braked trains and keep the rails corrugation free as much as possible.

In any case the current noise emissions are too high and measures are needed before the HSR can be used at full capacity.

6 REFERENCES

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