Maximum sound pressure level as an additional criterion for the assessment of railway noise at night: Acoustic criteria for the maximum-level in regulations

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Summary

In an interdisciplinary study it was examined whether the effects of rail noise on sleep were adequately assessed by the equivalent continuous sound pressure level. A reanalysis of existing studies on the psychological and physiological effects of nocturnal railway noise lead to the result, that in addition to the equivalent continuous sound pressure level, the introduction of 2 maximum-level criteria is required. By the determination of a maximum difference between the maximum sound pressure level and the equivalent continuous sound pressure level of 17 dB the psychological effects are considered; by introducing a maximum number of reasonable awakening reactions, the physiological effects are adequately considered. In order to implement these criteria, a calculation method for the evaluation of the maximum sound pressure level on the basis of Schall03 as well as a method for the further assessment were developed.

PACS no. PACS no. 43.50.Lj, 43.50.Qp, 43.50.Rq, 43.50.Sr, 43.64.Ri, 43.64.Yp

1.   Introduction

In order to implement the results of the psychological and physiological examinations into directives and regulations (see Müller et al. 2018 [1], Schreckenberg et al. 2018 [2]), a procedure is required for the computational determination of the acoustic exposure of those affected persons. The characteristic variables for the event-related effect of passing trains are based on different maximum-level definitions, which differ according to the level of detail of the forecast and the predictability.

This contribution is part of a study commissioned by the Hessian Ministry of Environment [3]

2.   Calculation method for maximum noise level

The calculation of the maximum level for railway noise is currently not regulated in Germany. Therefore, a calculation method for the maximum level was derived from the calculation method, which is introduced in the German noise regulations for railway noise "Schall03" [4] by using the method of NORD 2000 [5] as a limited linear sound source (corresponding to the train length). The line sound source - corresponding to the length of a train - is iteratively moved along the track and a propagation calculation to the immission point is carried out at each iteration step.

The propagation calculation follows the rules according to Schall03; which refers to ISO 9613-2 [6]. From these partial sources at each iteration step the immission level is calculated at the immission points. This way the time pattern of sound level is simulated, comparable with sound measurement following DIN EN ISO 3095 [7]. The calculation method can be integrated into the existing Schall03 calculation procedure.

The calculation values do not take into account that individual vehicles in a train may have different emissions (see fig.1), such as defective wheel sets (flats, polygons) or particularly loud bodies of goods wagons. In order to be able to map these temporally short level maxima in the forecast, individual short-term events are taken into account by a

distance-dependent level addition, in addition to the maximum level determined by the emitting line source. The basis is the measurement data from the
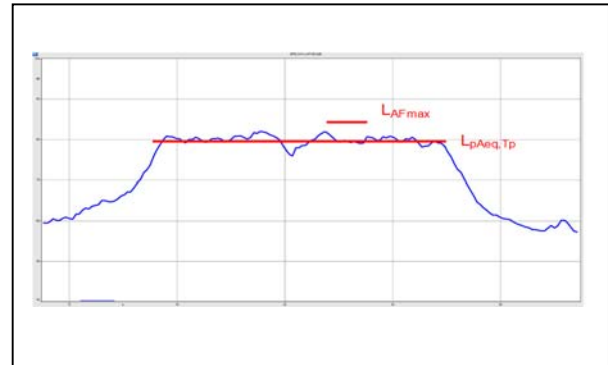

Figure 1. Definition of Maximum level according to DIN EN ISO 3095

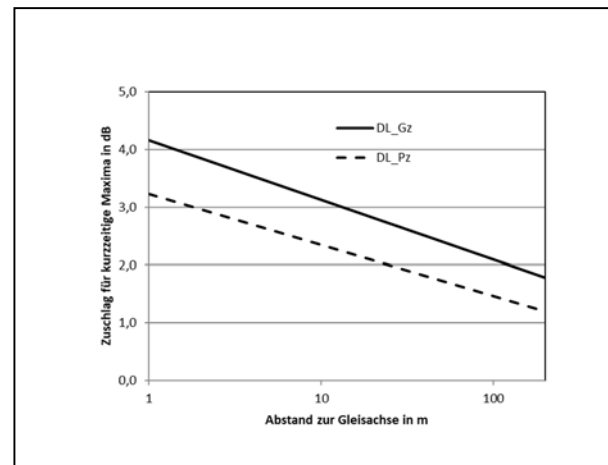DLR study [3]. the relationships are shown in Figure 2:

Figure 2. Relationship between extra charge for individual events and distance

The range of the extra charge decreases with the distance from about 3 dB(A) in the immediate area to 0 dB(A) at a distance of about 150 m.

3.   Acoustic description of sleep interference on the basis of psychological and physiological surveys

The reanalysis of the NORAH study (see [2]) has shown that the percentage of persons who are highly disturbed at sleep differs significantly, depending on whether the maximum level or the averaging level is used as the criterion. The exposure – response relationship for sleep disorders shown in

Figure 3 results in the fact that an immission threshold of 49 dB (A) based on immission targets of traffic noise in Germany during nighttime leads to an amount of 2.6% of indviduals who are particularly disturbed by sleep.

The same number of highly disturbed sleepers results in a maximum level outside of about 66 dB, as shown in Figure 3.
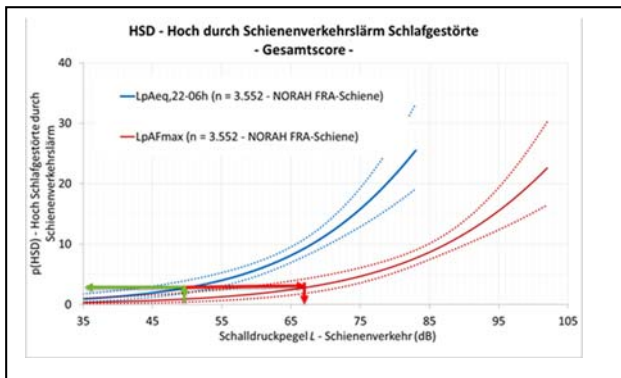

Figure 3. % Highly sleep disturped vs. L_{Aeq} and L_{Amax}

The result of the physiological part of the study was the relation between the probability of awakening and the maximum sound level inside of bedrooms (see[1]). In order to quantify the awakenings in a similar way as the psychological effects, the awakenings were related to the maximum sound level outside the room, the persons were sleeping in. Furthermore the number of awakenings had to be quantified for the night time, dependent on the total number of train pass-byes.

For the calculation of the number of awakenings (AWR) the following steps are necessary:

1.) Calculation of the maximum sound level by Schall03 for every single train
2.) Correction of individual events
3.) Correction of inside / outside
4.) Distribution of the maximum level with a standard deviation of 3 dB
5.) Calculation of the individual frequency of awakening dependent on single trains
6.) Accumulation of awakenings during night time between 10.00 pm and 06:00 am

Limits for the number of awakenings (AWR) at nighttime have not been introduced in Germany yet.

4. Case studies for the description of sleep interference on the basis of psychological and physiological surveys

The effects of %HSD and AWR as a supplementary assessment criteria in a possible regulation are shown in two very different case studies. Here a situation with a low traffic volume load with about 20 train pass-byes at night, of which 6 were freight trains, and a situation with a high volume of traffic with about 100 pass–byes with about 70 freight trains was selected. The calculations were carried out for immission sites in the vicinity of the tracks at a distance of 30 to 100 m from the track axis. The results are listed in following table 1:

Table 1. Results of the case studies without noise protection

Pass byes	$L_{r,N}$	L_{Amax}	L_{Amax}-$L_{r,N}$	Delta %HSD*	AWR
20 trains/night	60	87	27	4	1,2
100 trains/night	60	79	19	0,2	5,7

* %HSD L_{eq} -L_{Amax}

- The difference of %HSD between L_{Aeq} and L_{Amax} is particularly large in the case of low traffic volume
- The corresponding difference between those in the case of high traffic volume is small
- The number of train-induced awakening reactions (AWR) in the case of low traffic volume is only 1 additional AWR, whereas in the case of high traffic volume there are 6 additional AWR

In the case of noise protection for the same traffic situations the results are shown in following table 2:

Table 2. Results case studies with noise protection

Pass byes	$L_{r,N}$	L_{Amax}	L_{Amax}-$L_{r,N}$	Delta %HSD*	AWR
20 trains/night	48	74	26	1,9	0,8
100 trains/night	49	68	19	0,4	3,8

* %HSD L_{eq} -L_{Amax}

With noise barriers in both cases the L_{Aeq} as well as the L_{Amax} can be reduced to about 10 to 13 dB. As a result of the measures regarding the case of low traffic volume the %HSD is reduced by about 60% from 4 to 1.9, whereas the number AWR is reduced by about 30% from 1.2 to 0.8.
In the case of high traffic volume with noise barriers a significant reduction of AWR from 5.7 to 3.8 can be achieved whereas the reduction of %HSD is marginal.

5. Additional noise limits for maximum noise level

The reanalysis of the NORAH study has shown that there is a clear difference of %HSD depending on whether the L_{Aeq} or the L_{Amax} is used as a criterion. At the noise limit of 49 dB(A) in Germany the difference between the two levels is 17 dB. In order to avoid a higher %HSD based on L_{Amax} it is required that the maximum level does not exceed the averaging level by more than 17 dB. For practical application we propose a value of 15 dB(A) as a maximum sound level criteria. In addition the number of awakenings should be limited on 3 awakenings. Both assessment criteria are to be applied in addition to the regular noise limits related to the $L_{Aeq.}$
In practical application, these additional criteria lead to improved noise protection measures in the immediate vicinity of railway lines.

6. Conclusions

The reanalysis of existing studies on the psychological and physiological effects of nocturnal railway noise leads to the result, that in addition to the equivalent continuous sound pressure level, the introduction of 2 maximum-level criteria is s required:

The difference between L_{Amax} and L_{Aeq} is to be limited to 15 dB(A) and the maximal number of awakenings should not exceed 3 AWR.

In further steps, the calculation method for the L_{Amax} is to implement in standard calculation methods (Schall03, CNOSSOS-EU). Further tasks are finding a method to determine the AWR and discussing suitable AWR limits

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