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RAILWAY NOISE LONG TERM MONITORING: EXPERIENCES AND STANDARDISATION

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ABSTRACT

Railway noise is seen as Achilles' heel amongst environmental benefits of rail. In the last decade many efforts were done to reduce railway noise, but complaints are still existing and immission limit values might get lower in future. Monitoring of railway noise is a task raised in the near past, and currently some countries publish annual monitoring reports.

Railway noise monitoring aims to install systems for a continuous observation of the noise generated by railways. Usually, systems for such monitoring aims to (a) measure (b) noise emissions and accompanying parameters (c) of the real railway traffic (d) at a defined position along a line.

The paper gives insights in the experiences of monitoring stations in the Austrian railway network, where the first permanent site was installed in 2008 as research site. In 2009 and 2020 two additional sites were installed at main lines. The second focus of the paper is on the recent work item within CEN TC256 "Railway Applications" WG03 "Acoustics", where in 2021 the Subgroup L "Long term noise measurements" was installed; together with experiences from other countries a common framework for railway noise monitoring will be established.

Keywords: *railway noise, noise measurement, monitoring site, standardization*

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INTRODUCTION

Railways will be a main contributor to the 'Green Deal' Initiative of the European Commission to reduce greenhouse gas emissions. The greenhouse gas emission by rail transportation is considered by the EC as "marginal as it represents 0.5% of the emission produced by the transport sector" [1]. That is why rail is seen as "the backbone that supports an environmentally sustainable multimodal transport system" and the 'Renaissance of rail' is announced. With this, rail traffic will increase within the next decades.

On the other hand, noise emission produced by railways is seen as 'Achilles' heel' amongst environmental benefits of rail transport. That is why in the last decade many efforts were done to reduce railway noise emissions, e.g. the development of quieter brake blocks, in particular for freight wagons; the revision of TSI Noise and the coming of 'quieter routes' in 2024 [2]; or CEF-fundings for retrofitting of existing freight wagons.

Despite these efforts complaints are still existing and noise immission limit values might get lower in future because of recommendations by WHO [3]. An increasing number of trains will also result in an increase of noise immission when the emission of each vehicle stays the same and no additional noise mitigation measures are taken. While TSI Noise [2] is dedicated for type testing of new rail vehicles regarding noise emissions, monitoring of railway noise is a task raised in the near past to obtain reliable data on the development of noise emissions from railways in daily operation: some countries publish annual monitoring reports where the noise emission of the trains passing by at given sites along dedicated lines is measured, analysed and presented [4], [5], [6].

1. RAILWAY NOISE MONITORING

Railway noise monitoring is based on the existing railway traffic on a dedicated line, and mostly done as noise emission monitoring; noise immission monitoring, e.g. at the place of a resident, is usually rarely carried out because of additional noise influences by other noise sources or meteorological effects. Railway noise monitoring systems includes numerous components for a continuous measurement of the noise generated by railways: generally spoken, such systems aims to (a) measure (b) noise emissions and relevant accompanying parameters (c) of the real railway traffic (d) at a defined position along a line.

For the systems where an annual monitoring report is published [4], [5], [6], the sound pressure level is measured by microphone in the position at 7.5 m from the centreline of the track and at a height of 1,2 m above the upper surface of the rail which is given in measurement standard EN 3095 for the "Constant speed test" for type testing of units and is named as "A" microphone position [7]. It is that position which is of relevance when a new rail vehicle type is certified against limit values given e.g. in TSI Noise [8].

The calculations for the annual report contains in Switzerland [4] the assessment level (emission) Lr,e with reference to the Swiss Noise Protection Regulation [9] and the Transit Exposure Level of a train passing-by, normalised to the speed of 80 km/h (TEL 80). In Germany [5] the TEL80, the average assessment level (emission) Lm, the LAfmax and the LpAeq,Tp,APL,80 are included in the monitoring report, while in Austria [6] the LAeq,Tp,80km/h,APL=0.225 (median) for freight trains and LAeq,Tp,80km/h for passenger trains are reported. In addition, in Austrian report also immission-side assessment levels Lr,Tag for daytime and Lr,Nacht for nighttime for the given traffic is calculated for a distance of 30 m from the centreline of the track and with a noise barrier of 2 m height. Within the annual report of Switzerland [4] a sub-chapter is dedicated to "Comparison with measurements in Germany" where conversion parameters to LAeq,25m and to Leq,e are given.

In some other European countries, there are also railway noise monitoring sites installed, like Belgium and The Netherlands, but without similar published (annual) reports. In general, often these monitoring stations are dedicated to give evidence of retrofitting of wagons by noise measurements [10].

2. EXPERIENCES IN AUSTRIA

In Austria the first railway noise monitoring site was installed in 2008 as a research site, and from the beginning it was dedicated for long term noise emission measurement. It is situated at a double track main line with passenger and freight traffic and a maximum permitted speed of 120 km/h and northern of Vienna near the village of Deutsch-Wagram. In 2009 a second monitoring site was installed in Breitenstein at the Semmering line at one track of another double track main line, but here situated in a curve of only 180 m radius to gather information on the effects of curve squeal (maximum permitted speed of 60 km/h). Both sites are still in use as a research site to get long time experiences with measurement equipment, data collection and processing, data quality and data analysis. Recently, in 2020 a third site on a double track main line (maximum permitted speed of 130 km/h) was installed in cooperation with the government of the province Kärnten/Carinthia for railway noise monitoring nearby in the touristic Wörthersee region; the cooperation agreement included also to provide public annual reports of these measurement results. This site will also be used for railway noise research like to investigate dependencies of pass-by noise and wheel roundness parameters.

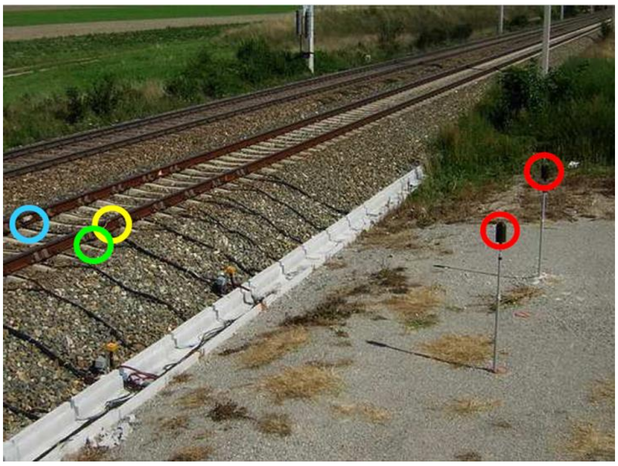

Figure 1. Noise emission monitoring site in Austria: red marked are the microphones (two, for data quality reasons), blue marked the wheel sensor for axle detection at the cross section of microphone and green and yellow marked the vertical and horizontal rail accelerometers. Photo: M. Kalivoda, © psiacoustic

The experiences gained from these noise monitoring sites covers several topics, like the following: weather data and track quality data (acoustic rail roughness and track decay rate) are recorded and in particular it is necessary to measure additional parameters like axle detection when a vehicle passes the microphone section, or to link to other data like train number and vehicle numbers. The durability of the measurement equipment in the rough environment of railways is another field of experience, in particular the fixing of the rail accelerometers for long term measurements. Data collection issues led to the setup of a xsd-scheme for datatransfer from the sites to the central database with xml-files. While in the early years the data were stored at the sites and manually brought together and analysed, in 2015 the central database was established and collects the data produced at the LTM-sites. Also wav-files are recorded for every pass-by. Data quality is ensured both by hardware, e.g. two nearby microphones for redundancy and comparison, and also by software, e.g. by automated data check when the xml-datafiles are imported in the database. Data analysis is now unified in the case of the annual reports [6] but kept open for individual queries like in research projects: while at the first site mentioned above the 'Europe train' with low-noise brake blocks passed by in 2011 [11], at the Breitenstein site the internal research project "WORMS" to avoid curve squeal noise by friction modifier systems was performed in 2013. The first analysis of pass-by noise data and wheel roundness data was done with data from the site Deutsch-Wagram in 2016 [12], [13], [14]. Finally, ad-hoc data investigations for different reasons are also done on request of internal departments or wagon maintenance holder (see Fig. 2), and also to provide data for national and international research projects or CEN-working groups.

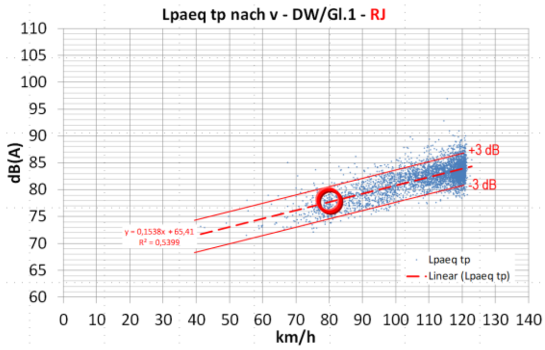

Figure 2. Chart of noise-speed dependency of express train type (type "RJ") on track 1 of Deutsch-Wagram site with data from the year 2018 and simple markings of averaging and +/- 3 dB range.

An important outcome of the long term monitoring site in Carinthia is the annual report "Monitoring Schallemissionen Eisenbahnverkehr Wörthersee" (Monitoring Noise emissions railway traffic Wörthersee) [6].

Figure 3. Annual report on noise emission monitoring at Wörthersee [6].

The aim to publish such a report was to make a documentation of the development of railway noise when the 'quieter routes' will come in force at the end of 2024 and its impact on the residents living along Lake Wörthersee. This overall use-case led to discussions of the key data presented and at the end the annual report covers three types of result data: first, the share of quiet freight wagons running on this line; secondly, the median of the pass-by noise level of freight trains by year to illustrate the development of the levels towards quieter (freight) trains; and finally, based on this noise emissions measurement, an exemplary calculation shows the noise immission at a defined distance of 30 meters from the tracks. It is carried out both without and with a noise barrier (2 m height) in the sound propagation path while the main result is this one with noise barrier.

The first report was published in 2021 with data from two months of 2020. The recent report with data of the whole year 2022 shows now that (based on wagon-lists) the share of quiet freight wagons has reached even 90%. The median of the pass-by noise levels LAeq,Tp,80km/h,APL=0.225 for freight trains is 86,1 dB(A) and contains the noise measurement of 14,277 trains. Finally, for all trains passed there in 2022, the assessment noise level for night (Lr,Nacht) is 45 dB(A) with noise barrier and 69 dB(A) without noise barrier (see Fig. 4).

Messstelle Wörthersee / Lind ob Velden	2020 *	2021	2022
Anteil an leisen Güterwagen (vgl. Kap. 5.1)	64 %	83 %	90 %
Durchschnittlicher Vorbeifahrtspegel (Median, Entfernung 7,5 m): - Güterzüge ($L_{Aeq,TP,80km/h,APL=0.225}$; vgl. Kap. 5.2) - Personenzüge ($L_{Aeq,TP,80km/h}$)	 88,2 dB 77,5 dB	 87,2 dB 76,9 dB	 86,1 dB 77,2 dB
Daraus beispielhaft berechnet: **Beurteilungspegel** (Entfernung 30 m, Erdgeschoß) (mit Lärmschutzwand, vgl. Kap. 6) $L_{r,Tag}$ $L_{r,Nacht}$	 46 dB 48 dB	 45 dB 46 dB	 44 dB 45 dB

Tabelle 1: Zusammenfassung der Ergebnisse der Messstelle Wörthersee / Lind ob Velden

Figure 4. Table from [6] with overall results by year: share of quiet wagons (first line), average pass-by level of train types, normalized for 80km/h and APL for wagons (middle section), assessment noise level for day and night at distance of 30 m with noise barrier (lowest section).

Of special interest is the chart of the pass-by noise level group (width of 1 dB) of freight trains (normalized for 80km/h and the APL of 0,225) and frequency of occurrence of each group for the years 2020 (only 4th quarter), 2021 and 2022. This chart shows that the peak of the distribution of pass-by noise level grouping was lowered from 90 to 88dB and the share of level groups higher than 90dB were halfed to tripled (see Fig. 5).

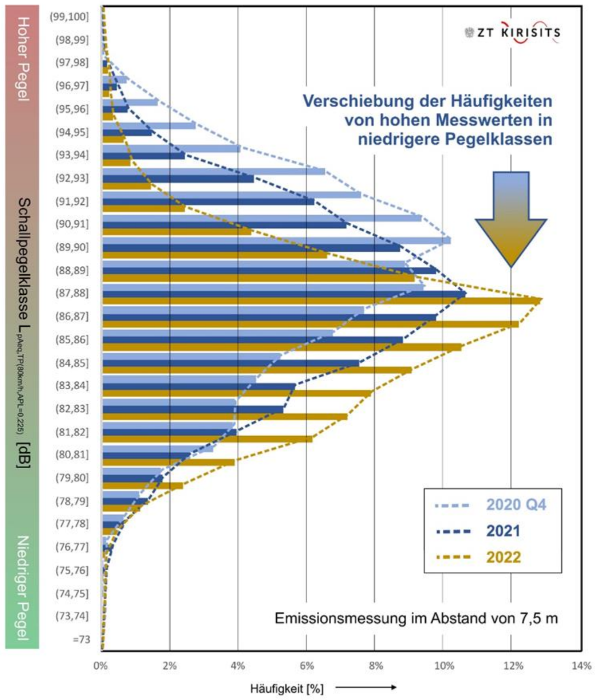

Figure 5. Chart from [6] with pass-by noise level group of freight trains (normalized for 80km/h and APL of 0,225) and frequency of occurrence for the years 2020 (only 4th quarter), 2021 and 2022.

All of this analysis cases were made with the measurement data of the real train pass-by's on real track and under real environmental conditions. To make it comparable it is important to normalize the pass-by levels for 80km/h to compensate times during the year where the speed was reduced because of e.g. construction works. For data analysis of pass-by noise levels it is e.g. important to exclude measurement data when a second train passes on the other track of a double track line. Up to now, no normalizing was done for rail roughness or track decay rate, or snow on the trackbed; but such information was collected and documented.

With the help of additional data the analysis will become much more detailed or opens new areas of interest: operating data like individual vehicle numbers, or tagged vehicles with RFID and long term noise measurement will open up the opportunity to show time series of the pass-by levels and will give an 'acoustic fingerprint' of a dedicated vehicle (as remark, this measurement must be distinguished from axlebox sound measurement to identify axle bearing failures).

3. WORKING ON AN EUROPEAN STANDARD

Due to the upcoming demand in some countries to publish railway noise monitoring reports in the last years, it was discussed within the CEN working group for EN 3095 to apply parts of this standard not for type testing like given by the scope, but for long term noise monitoring: but some elements of the EN3095 framework cannot be used or guaranteed in daily railway operation. Finally, the decision not to include it into EN 3095 but to hand it over to a New Work Item (NWI) was done in 2021. The European National Standards Committees voted for this NWI to create a new Technical Specification (TS) and agreed as follows: "The new document will declare the limits and differences of long-term measurements and type testing measurement needs, and compile the framework which aspects of EN ISO 3095 shall be used when long-term measurements are intended (including information of the variations of the outcome of long-term noise measurements). The new document will be as close as possible from the EN ISO 3095 (especially regarding the measurement positions and the measurement procedures)."

In 2022 the Subgroup L "Long term noise measurements" (LTM) was installed within CEN TC256 "Railway Applications" WG03 "Acoustics", and 13 members from 6 European countries started the work on this new standard. Both the given EN 3095 and the experiences of members including the reference to DIN 38452-1 forms the background, while the quality of the measurement of railway noise is defined within NWI specification 'as close as possible' to EN 3095, which is well known in the field of railway noise emission measurement.

First and most important was to identify and discuss the use(s) of Long Term Noise Measurements and to make a draft of the scope of this new TS; based on this common understanding, the structure of the content was established which is the framework of the topics to regulate.

The identification of use(s) of Long Term Noise Measurements as a first step is of central importance to avoid overboarding data measurement and data storage; it is the basis to identify the measurement setup needed and appropriate for the desired use case. Although use cases may be manyfold, they will determine the whole setting: within the group a systematic and overall view was done by using a questionaire. In there, three principal types of use cases were identified:

- to provide regular noise monitoring data of a / more site(s)
- to provide regular noise monitoring data of a fleet
- to provide regular noise monitoring data of unit(s)

Within these LTM principal types – which of course may overlap – 19 LTM result types were identified. All of these were rated by the members of the group in relation to the importance but also in relation to the readiness of technological systems. This rating resulted in a ranking of nine LTM result types to be further discussed:

- pass-by measurement of sites with same (track) parameters
- validate the emissions of calculation models at different sites
- average noise emission by train type for time interval (e.g. year, etc)
- statistical distribution of noise emission by train type
- collect basic source data for noise calculation (by train type)
- validate the emissions of calculation models for a fleet
- chronological trend of noise emissions of single units (e.g. for maintenance issues, detailed by axle)
- comparison to limit values (e.g. TSI NOI) of an unit
- validate the emissions of calculation models of an unit

Based on this list of use cases, the scope of this TS was drafted, discussed, and finalized as follows: "This Technical Specification specifies long-term measurement methods to obtain trackside noise emission values of multiple train pass-bys, automated and unattended, of all kinds of vehicles operating on rails in regular operation, taking into consideration the specific environmental, track and vehicle conditions.
It specifies conditions such as measurement setup, data analysis and data processing methods.
The results are data-sets of pass-by sound pressure levels or third octave spectra for different sites, train types, units (vehicles) which may be used for different reporting objectives and data analysis."

Up to spring 2023, within the group the list of content was compiled, discussed and agreed, which will contain a total of ten chapters: Scope; Normative references; Terms and definitions; Instrumentation and calibration; Conditions, including environmental, track and vehicle conditions, and measurement positions; Measured quantities; Test procedure; Data processing; Quality of LTM; LTM Report.

For a better understanding also a procedure for LTM was drafted and contains eleven steps, which are still under discussion:

1. declare and/or specify the use case, in particular the quantities needed in the LTM Report (report quantities)
2. identify noise measurement parameters
3. identify additional measurement parameters
4. Identify time of ‚long term'
5. Identify site parameters (use case specific, like e.g. track geometry)
6. Identify measurement equipment
7. Identify data flow & data architecture
8. Installation (of sensors, data collector, data storage / database) & setup, including initial quality control of system
9. MEASUREMENT
10. Analysis of (measurement) data, including calculations (use case specific) to determine report quantities
11. Reporting

The next steps are to start drafting the chapters: this will be done on one hand to prove the framework of the conditions given in EN 3095 for pass-by measurements regarding its applicability for LTM, and on the other hand to identify which ones cannot be fulfilled. Based on this it is also necessary to estimate the deviations because of this different use case of single pass-by's of trains in scheduled traffic instead of multiple pass-by's of rail vehicles for type testing. For example, in scheduled operation the train speed cannot be chosen like specified in EN 3095 chapter 6.6.2, also a speed stability within +/-5% cannot be guaranteed but will (mostly) occur at well-chosen LTM-sites; nor 'a series of at least three measurement' runs, or 'at least two units under test' of the train composition as given in EN 3095 chapter 6.3.4. can be guaranteed at LTM sites. In addition, the same analysis and adjustment will be done with DIN 38452-1 which also addresses long term noise measurement but splits up in three quality levels and is limited to only one microphone position.
The LTM-subgroup meets around four to five times a year both 'live' and virtual. With reference to the CEN-guidelines it is planned to have the final draft in autumn 2024. Afterwards the enquiry process within CEN will start and when all the comments from the standards institutes of the different countries have been incorporated, the (final) formal vote process will take place to set the TS in force.

4. CONCLUSIO

Noise long term monitoring is an upcoming task. Within the last years some countries installed railway noise monitoring stations and some of them also publish annual railway noise monitoring reports. These are dedicated to give evidence to the public of the sound emitted by railway traffic and its reduction in the case of freight trains: new (brake) technology result in a lower roughness of the wheel surface and this is the reason for lower sound emissions. Beside this use case also other use cases are of interest, e.g. to test and validate new noise reducing measures or to determine the levels for noise calculation and noise mapping to handle the upcoming 'Renaissance of rail'. In all these cases there is a high demand for robust and/or typical data which implies to measure a high number of trains.
As sound generation at railways is difficult and requires knowledge, accuracy in measurement as well as the recording of some additional parameters. For quality reasons such sound measurement sites have to be equipped with several devices which also have to fulfil requirements for working in such a rough environment. Experiences of railway noise long term monitoring exist in some countries: within Austria the first sites were installed in 2008 and since 2015 the data management is carried out by means of a central database. These data are used in research projects and demonstration projects like the 'Europe train' with low-noise brake blocks (see Fig. 6). Other use-cases are ad-hoc data investigations or -published- annual reports on average noise by scheduled rail traffic.

Figure 6. UIC 'Europe Train' at noise emission monitoring site 'Deutsch Wagram' on Sept. 9th, 2011 [11].

This growing demand of railway noise long term monitoring leads to a recent working group within CEN TC256 "Railway Applications" WG03 "Acoustics" to identify and standardize the framework and requirements for 'Long term noise measurements' of railway noise. This will ensure the quality needed for noise emission measurement for different use cases like proof of evidence and data collection for noise mapping issues.

5. REFERENCES

[1] EUAR (Ed.), "Report Fostering Rail Through Green Deal (ERA1234), Valenciennes: EUAR, 2022, see URL: https://www.era.europa.eu/system/files/2022-09/Report%20-%20Fostering%20the%20railway%20sector%20through%20the%20European%20Green%20Deal.pdf, 17.4.2023.

[2] European Union: Commission Implementing Regulation (EU) 2019/774 of 16 May 2019 amending Regulation (EU) No 1304/2014; see URL: http://data.europa.eu/eli/reg_impl/2019/774/oj, 17.4.2023.

[3] See e.g. WHO (Ed.): Environmental noise guidelines for the European Region, Copenhagen: WHO, 2019; see URL: https://apps.who.int/iris/rest/bitstreams/1175318/retrieve, 17.4.2023.

[4] Bundesamt für Verkehr (Hg.): Monitoring Eisenbahnlärm; Bern: BAV, 2022; see URL: https://www.bav.admin.ch/bav/de/home/verkehrsmittel/eisenbahn/bahninfrastruktur/ausbauprogramme/weitere-ausbauprogramme/laermsanierung/monitoring.html, 17.4.2023.

[5] Eisenbahn-Bundesamt (Hg.): Jahresbericht 2021 Lärm-Monitoring Schallmessungen im Schienenverkehr; Bonn: EBA, 2022; see URL: https://www.laerm-monitoring.de/Jahresbericht, 17.4.2023.

[6] Land Kärnten, ÖBB-Infrastruktur AG (Hg.): Monitoring Schallemissionen Eisenbahnverkehr Wörthersee. Bericht 2022; Klagenfurt / Wien: Land Kärnten, ÖBB-Infrastruktur AG, 2023; see URL: https://konzern.oebb.at/de/leise-gleise/massnahmen/schallschutz-bestehende-infrastruktur/woerthersee, 12.5.2023.

[7] EN ISO 3095:2013: Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles

[8] European Union: Commission Regulation (EU) No 1304/2014 of 26 November 2014 on the technical specification for interoperability relating to the subsystem 'rolling stock — noise'; see URL: http://data.europa.eu/eli/reg/2014/1304/oj, 17.4.2023.

[9] Schweizerische Eidgenossenschaft: Lärmschutz-Verordnung (LSV) vom 15. Dezember 1986 (Stand am 1. Juli 2021), see URL: https://www.fedlex.admin.ch/eli/cc/1987/338_338_338/de, 17.4.2023.

[10] UIC: Railway Noise in Europe. State of the art report; Paris 2016, see URL: https://uic.org/IMG/pdf/railway_noise_in_europe_2016_final.pdf, 17.4.2023, p.29.

[11] UIC: The international "Europe Train" with low-noise brake blocks starts new test loop in Austria, see URL: https://uic.org/com/enews/nr/254/article/le-train-d-essai-europe-train-fait?page=modal_enews, 28.4.2023.

[12] T. Maly, G. Dinhobl, M. Jaksch: Schallemissionen von Laufflächendefekter; in: Eisenbahntechnische Rundschau (ETR) 12/2016, p. 68-71.

[13] T. Maly, G. Dinhobl: Zug- und fahrzeugspezifische Untersuchungen der Auftrittshäufigkeiten erhöhter Schallemissionen in Gleisbögen; in: HTW und TU Dresden: Tagungsband 15. Internationale Schienenfahrzeugtagung, Dresden 2017.

[14] T. Maly, G. Dinhobl: Variationen in den akustischen Auswirkungen von Laufflächendefekten; in: Müller BBM (Ed.): BAHNAKUSTIK Infrastruktur, Fahrzeuge, Betrieb; München: MBBM, 2018.

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