Managing noise from parked trains

Nathan Isert and Stefan Lutzenberger
Müller-BBM GmbH, Robert-Koch-Str. 11, 82152 Planegg, Germany.

Nick Craven, Peter Hübner and Jakob Oertli
INTERNATIONAL UNION OF RAILWAYS, Paris, France.

Summary
Noise from parked trains is an increasing problem. The urban development of sites in close proximity to train yards, the increase in trains parked in densely populated areas and the parking state of the trains, that often need to be short term ready are some reasons. In addition to this old trains are more and more being exchanged with modern multiple units (MU) that generally come with a far larger number of technical aggregates installed to grant maximum comfort and safety. The fact that this exchange may also raise the noise annoyance level of the parked trains has so far found too little concerns in preliminary assessments and subsequent procurement specifications. This paper summarizes the findings of a research project [1] aimed at defining the parking noise problem for trains and collecting counter measures. Data was raised by sending out questionnaires, conducting telephone interviews and performing a literature study. We therefrom identify noise relevant processes, list generalized noise abatement measures and strategies and deduce a cost benefit ranking for them.

PACS no. 43.50.Gf, 43.50.Lj

1. Introduction

Public transport is highly in demand in densely populated regions. Particular local and regional train services are heavily depended on. Therein frequent services as well as late night and early morning availability are generally welcomed [14]. This in return requires a large number of trains, which will often be parked and kept short term ready in close proximity to dwelling areas. In particular during nighttimes, residents to these dwelling areas may be annoyed and disturbed in their sleep [4] by noise emissions related to the parking of the trains.
The reasons and causes for the noise emissions of parking trains are manifold [2][3][6] and the noise management can be complex, as different parties, like infrastructure managers, rail operators and owners are involved in the process. Largely parking train noise relates to the noise emitted from technical aggregates on the train.
In passenger transportation old fashioned composites of locomotives carrying passenger coaches are more and more being exchanged with modern multiple units (EMU/DMU), that generally come with a far larger number of technical aggregates installed to grant maximum comfort and safety [2][1].
Dependent on the operational state the train is parked in some of these aggregates will emit noise even during the rest times of the vehicle. Noise levels may rise with arriving or departing trains and therefore staggering of arriving and departing trains will further intensify the problem.
The interests of the different parties involved may be in conflict to each other. Rolling stock operators will need to fulfil transportation contracts and respond to passenger demands, which may require parking trains in close proximity to dwelling areas and keeping them short term ready over the entire parking period to save time and costs and meet comfort and safety standards. At the same time local residents annoyed by parked train noise and their legal representatives may labor to have the trains shut down for parking or banned entirely from their parking sites. Finally, preliminary assessments of the parking noise issue in procurements or the retrofitting of trains with silent aggregates need the financial support of the fleet owners.

Nathan.Isert@mbbm.com

2. Noise relevant sources and procedures

In the following we will list the most prominent noise sources and procedures in relation to parking trains. The presented data is a compilation of the data collection presented in [1] that was raised by sending out questionnaires, conducting telephone interviews and summarizing relevant literature [2][3][5][6]. An emphasis thereby is laid on passenger trains.
The following list summarizes the most relevant noise sources on parking trains:

- **HVAC** (heating ventilation and air conditioning) comprising air-conditioning compressor as well as cooling and ventilation fans as relevant noise sources.
- **Fans** and **pumps** used for cooling of all technical equipment such as engines, generators, traction motors, transformers, auxiliary converters, etc.
- **Main air compressor** that is used to supply compressed air on the train needed for braking and maintaining contact pressure on the pantograph. Identified as the main intermittent noise source.
- **Compressed air dryer** used for drying of the compressed air in the main compressor. The blowing out of the condensate is identified as the major impulsive noise source.
- **Power supply** over the parking duration by use of diesel engines, generators, batteries or taken by current collector (pantograph). Can require activity of transformers, converters, and cooling fans and pumps as well as compressors.

The annoyance level of noise may rise if tonal components are present [4] [11].
The individual levels of activity and therefore the noise emissions of these aggregates will strongly depend on the state the train is left in over its parking duration. The following list comprises the most commonly used parking modes (states defined in the software control system used for parking of the train):

- **Standstill** leaves the train fully operational with engines on idle and the pantograph raised. Often some aggregates activity can be tuned down. Meant for halting at terminus stations and signals but sometimes also used for short time parking.
- **Shutdown** refers to a state where the train is shut down entirely and therefor does not emit any noise. Engines are switched off and the pantograph is lowered. However, to prepare the vehicle for shut down and bring it back to service may require time and have the train in a state where it will be particular noisy. Electric driven trains rely on batteries, generators or external power for building up pressure to raise the pantograph.
- **Sleeping** refers to an optimization of power consumption over the entire parking duration. The pantograph remains raised but every unneeded aggregate is switched off. Vital components such as air compression for the pantograph or heating and cooling are active, yet will generally be tuned down to save energy. The effort to put the train back to service is significantly reduced compared to a complete shutdown. This is an automated software controlled state.
- **Parking** describes the ambiguous state used for the parking of trains that does not fall in one of the other categories. Activity of aggregates and hence noise emission varies strongly, dependent mainly on the software control and the equipped hardware.

In addition to the above mentioned noise sources the arrival and departure of trains to and from the parking site may entail the following noises: rolling noise, braking noise, traction noise, curve squeal, and noise from assembling and dissembling of train units [5][13]. Shunting noise will not specifically be addressed in the following as the main focus lies on parked train noise.

3. Regulations on parked train noise

In Europe regulations on noise emissions from trains are generally covered by the TSI NOISE [7]. Limit values are defined for pass by, starting and standstill for different categories of trains. Standstill measurements require a defined activity level of aggregates and therefor do not represent the parking situation. The incorporation of intermittent and impulsive noise limits in the latest version of the TSI on standstill measurements does not resolve this problem. TSI limits will only apply to new or substantially upgraded rolling stock.
Reception limits for rail noise in Europe are subject to national legislations [7] [9]. Immission regulations generally only apply to the infrastructure such as the railway and rail yards and not to the trains themselves. Often limits are compulsory only for new or substantially

upgraded railway lines (yards). Parked train noise is in some countries treated as rail noise and in others as industrial noise.

4. Mitigation of parked train noise

The listed methods for noise mitigation were deduced from the questionaire responses in [1] and the literature study with the focus on [2][3][5][6]. Counter measures to parked train noise may be divided into three categories.

1.1. Technical measures

Technical measures try to reduce the noise at its source, the train. They comprise the following measures and can be applied to new rolling stock as well as to existing trains.

- **Noise optimised operating condition** refers to the software implementation of quiet parking states, i.e. by reducing fan speed, cooling with outside air only or lowering the working hysteresis of compressors. This is often analogous to an optimisation of power consumption. Benefits are medium and dependent on hardware. Cost will be medium to high.
- **Encapsulation** of particular noisy aggregates such as compressors or engines may drastically reduce the noise emitted from them. Benefits are medium and costs are medium to high.
- **Silencers** are specifically useful for the blow-off valve of the compressed air but may also be found for fans. Dampers on the quick-acting valve of the braking system can reduce the impulsive noise components from the sudden air pressure release for braking trains. Costs are moderate and benefit is medium.
- **Retrofitting** refers to the replacement of particular noisy hardware components (entire aggregates or parts of them) with silent state of the art equipment. Cost can be high and benefits will generally be medium to high.
- **Maintenance** cycles for all noise relevant aggregates will help to prevent unnecessary noise from malfunctioning components. This measure has low benefit and medium costs unless done alongside regular maintenance.

It will generally be more benefitial and less costly if the noise countermeasures at the sources were already be considered and implemented in the construction phase of the train. This requires that parking noise enters into procurement specifications as TSI regulations are not sufficient.

1.2. Operational measures

Operational measures will attempt to minimize noise immissions for a given situation by optimizing operational procedures and repositioning noise sources (trains).

- **Noise optimized parking positioning** refers to the attempt to minimize noise immissions by parking noisier vehicles in spots that are less sensitive to noise. Requires knowledge of noise source levels of trains and their main contributors. Benefits will generally be low and so will the costs.
- **Shielding with trains** by parking less noisy or even noise neutral rolling stock such that direct lines of sight to residential housings are blocked. Shielding will be less for aggregates on the roof of the train. Benefits are low and costs as well. Does not justify shunting.
- **Reduce operator's procedures** on site by training staff to minimize noisy actions on site i.e. by manually tuning down or switching off noise relevant aggregates before arrival and turning them on again only after departure. The effectiveness will be limited if noise optimized automated parking modes are installed already. Training costs are moderate and stir awareness of the issue in staff.
- **Relocation** of particular noisy trains to other depots in less noise sensitive surroundings. Benefits depend strongly on accessibility of appropriate vacancies on nearby sites otherwise costs can be high due to increase in staff time for the parking procedure.
- **Feedback systems** that involve staffs as well as local residents may help to quickly detect malfunctioning aggregates and the use of unintended noisy parking modes and may increase the acceptance for necessary noise emissions from rail yards. Benefits are low and so will the costs.

Generally all processes that require additional regular staff time will be costly on the long terms. Also often operational measures are limited regarding sound reduction and will otherwise only relocate sound sources. In particular in densly populated ares where the parking noise issue is strongest the relocation option is limited.

1.3. Infrastructural measures

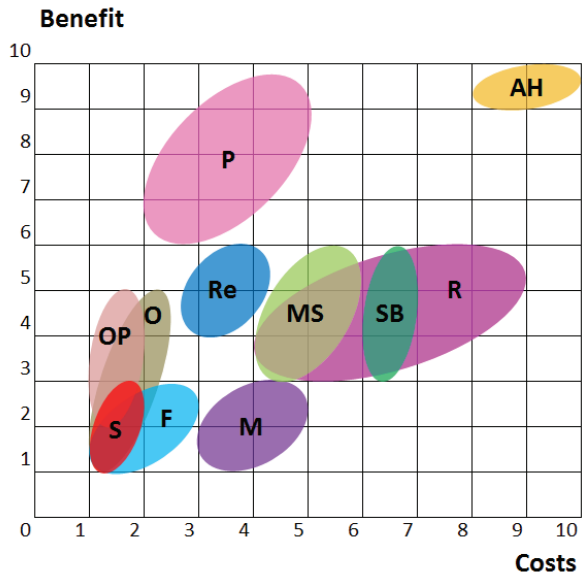
Infrastructure measures generally are measures to alter sound propagation, hence taking an effect only at certain immission locations.

- **Sound barriers** will reflect and absorb noise, thus reducing sound levels behind them. They will be effective only within a limited area behind the screen and if the height of the noise barrier is higher than the location of the sound sources and the source itself is close to the barrier. Otherwise effectiveness is reduced. Costs for sound barriers are medium to high while benefits are medium.
- **Main supply** of external pressure and power from stationary shielded compressors and generators at the parking sites can help to prevent particular noisy situations such as idling diesel engines. Costs are medium to high, dependent if trains need to be retrofitted with connectors. Benefits are medium.
- **Acoustic halls** are housings for the trains that will mitigate sound propagation in every direction very effectively. Cost are very high.

Which measures should be taken will depend on specific boundary conditions but will also have to consider costs and benefits.

1.4. Assessment of noise mitigation methods

To evaluate the usefulness of the above given noise mitigation methods a number of parked train noise experts were asked to give their judgement regarding costs and benefit of the individual noise abatement methods.
The results are presented in Figure 1. The data presented shows a clear priority of noise abatement in the procurement of the train. It is the by far most beneficial way to prevent parked train noise situations while at the same time saving overall costs. This measure should be prior to all other measures.
Acoustic halls provide also a very high benefit, are however more expensive.
For existing fleets the retrofit of the trains (silent components, silencer, encapsulation, software modes), noise optimized parking positions, reduced operator's procedures on site, the relocation to other depots, sound barriers or a main supply may improve existing parking noise problems.
All other measures are limited in their effect, even if a considerable amount of money is invested.



P	**P**rocurement specifications (encapsulation, silent components, silencer, software modes)
R	**R**etrofit (silent components, silencer, encapsulation, software modes)
M	**M**aintenance
O	Noise **O**ptimized parking position
S	**S**hielding with noise neutral rolling stock
OP	Reduced **O**perator's **P**rocedures on site
Re	**Re**location to other depots
F	**F**eedback system
SB	**S**ound **B**arriers
MS	**M**ain **S**upply
AH	**A**coustic **H**alls

Figure 1: Costs and benefit analysis of the most prominent noise prevention methods. The by far most benefitial way to prevent parked train noise is to consider it in procurements.

5. Conclusions and guidelines

General guidelines may be deduced from the assessment of the parked train noise issue sketched above and from literature [6][5][10][12]. Guidelines may individually be given to infrastructure managers, fleet operators and owners. The following list comprises a shortened summery of these guidelines:

- The highest attention should be paid to the procurement of new trains. It is vital to define appropriate noise related parking modes in procurement contracts as current noise related legislations in Europe generally do not specify parking noise limits. Procurements could also

contain requirements for preinstalled technical noise mitigation measures such as silencers for the dryer's blow-off valve or shielding/encapsulation on engines and compressors.
- Retrofitting of hardware and/or software components should be considered if a few particular noisy trains dominate the noise emissions at a site.
- Minimize train movements to prevent unnecessary rolling, braking and accelerating noise.
- Have trains stay in noise reduced (parking) modes for as long as possible. Parking modes need to be made available by the manufacturer, which may require retrofits.
- Instruct train drivers to reduce noise at parking sites by accelerating and braking gradually and keeping train speeds slow and by tuning down noise sources before arrival and turn them back on only after departure. Signs may be used as a reminder for train drivers to reduce noisy operations when entering parking sites and feedback systems (from residents or automated) may be used in combination to ensure that the intended optimized parking modes are being used.
- Instruct maintenance and cleaning staff to minimize noise emissions by working only on a few trains at a time and immediately restoring a noise reduced (parking) mode on the train when done.
- Noisy trains can be shielded (by barriers close to the rail and acoustic halls) or assigned to yards/sidings in less noise sensitive vicinities.
- Parking positioning of trains should correlate with time staggering of their arrivals and departures in such a way that night time noises are emitted furthest away from residential housings.
- Involve local residents (by informing them and letting them give feedback).
- To avoid future conflicts consult with planning authorities as far as development of sites close to depots and railways are concerned. A general guideline for preferable building shapes and interior room layouts is given in [5].

To account for parked train noise in procurement it is important to be able to give realistic approximates for the required maximum noise levels that the new trains may add to the noise levels from the existing trains. The limits requested in procurements must be technically feasible or else the specification is at risk to be ignored.
To prevent parked train noise issues one needs to consider the maximum noise contributions a new train may add at the most critical rail yards and sidings. If no tools are available to calculate the maximum added noise contributions the following simplified model may be used to obtain a rough estimate. Therefor some assumptions need to be made:

- The reception point (i.e. residential housing) lies within 15 - 100 m from the rail yard so that a train can be modelled as a line source.
- It is assumed that new trains are parked on the tracks close to the reception points.
- The length of the trains is assumed to be at least 50 m.
- The ground level is assumed to be flat
- Noise barriers are not considered can however be included in the calculation.
- The emission noise level from all new trains to be added to the yard is derived from the condition that the sum level of the existing noise plus the noise added from the new trains is at each reception point smaller than the most critical noise indicator value.
- Attenuation of sound during propagation outdoors is neglected (just geometrical attenuation is considered)

Modelling the yard as a line source is a rather conservative assumption as well as the fact that shielding effects from the new trains are not taken into account. The topographical parameters can go either direction, wherein raising ground levels around the yard will generally intensify the noise problem (as well as tall buildings).
The noise indicator value for a given area is defined in national legislations either regarding rail traffic noise or industrial noise immissions. In general the most critical indicator value is L_{night}. For residential areas the average value of L_{night} is 52 dB(A) for rail traffic noise legislations (Europe) and 48 dB(A) for industrial noise legislations. The indicator value changes for different types of areas that were assigned different degrees of noise sensitivity; it also may differ from country to country.

To make an approximation of the maximum emission levels for a parked new train a number of parameters needs to be known:

1. $L_{\mathrm{p,old}}$ = current sound pressure level at reception point. This can i.e. be approximated from a measurement of $L_{\mathrm{pA,night}}$ (no extreme weather conditions) at the reception point, if the critical noise indicator is L_{night}.
2. D = shortest distance from reception point to railway tracks.
3. N = number of new trains to be added to the rail yard at the track close to the reception point.
4. $L_{\mathrm{p,crit}}$ = critical noise indicator value (reception limit).

To estimate the maximum average sound pressure level $\overline{L}_{pA,train}(7.5\,m)$ the new train may have in a distance 7.5 m from centre of track the following formula may be used:

$$\overline{L}_{pA,train}(7.5\,m) \leq 10 \cdot \log\left[\frac{D}{N \cdot 7.5\,m} \cdot \left(10^{L_{p,crit}/10} - 10^{L_{p,old}/10}\right)\right]$$

$\overline{L}_{pA,train}(7.5\,m)$ is the energetically averaged sound pressure level of a train in a distance of 7,5 m from the centre of the rail. $\overline{L}_{pA,train}(7.5\,m)$ is averaged energetically over the length of the train and over the relevant time span of $L_{p,\mathrm{crit}}$ (including all noise emissions of the different parking conditions of the train in that time span).

Acknowledgement

This project has been funded by the Department for Sustainable Development of the INTERNATIONAL UNION OF RAILWAYS.

References

[1] UIC research project "Managing noise from parked trains" conducted by Müller-BBM, 2014

[2] Bafu: "Beurteilung und Begrenzung des Lärms von abgestellten Zügen", Empa-Nr. 460'395-2, 2012.

[3] TÜV Süd: "Lärmschutzgutachten zur Fahrzeugabstellung von Stadtbahnfahrzeugen", ID 82781 G (Revision 6.0), 2010.

[4] WHO: "Night noise guidelines for Europe", World Health Organisation regional office for Europe, 2009.

[5] SILENCE: "Practitioner Handbook for Local Noise Action Plans", SILENCE research project co-funded by the European Commission, accessed June 2014.

[6] SoFa-R: "Standlärm optimierte Fahrzeugabstellung der Reisezüge – Grobkataster z. Hd. BAV", SBB AG, Infrastruktur, Anlagen und Technologie, Lärm, 2014.

[7] COMMISSION REGULATION (EU) No 1304/2014 on the technical specification for interoperability relating to the subsystem 'rolling stock — noise', 2015

[8] Ødegaard & Danneskiold-Samsøe A/S: "A Study of European Priorities and Strategies for Railway Noise Abatement - Annex I: Retrieval of Legislation", 2002.

[9] Report study by Milieu Ltd., Risk and Policy Analysis Ltd. (RPA) and TNO on contract with the European Commission: "Review of the Implementation of Directive 2002/49/EC on Environmental Noise", 2010.

[10] S.N. Hoogzaad, M.S. Roovers: "Optimizing capacity of railroad yards within noise limits using a dynamic noise model", proceedings of the 11th International Workshop on Railway Noise Uddevalla, 2013.

[11] U. Landström, E. Åkerlund, A. Kjellberg, M. Tesarz: "Exposure levels, tonal components, and noise annoyance in working environments", Environment International, Volume 21, Issue 3, 1995, Pages 265 – 275.

[12] Research network – silent traffic: "Status report – Noise effects – Research in Germany", 2013.

[13] M. Ögren: "Noise emission from railway traffic", VTI rapport 559A, Linköping, 2006.

[14] ERRAC: "Rail Route 2050: the sustainable backbone of the Single European Transport Area", ERRAC Roadmaps, FP7 project, (2013).