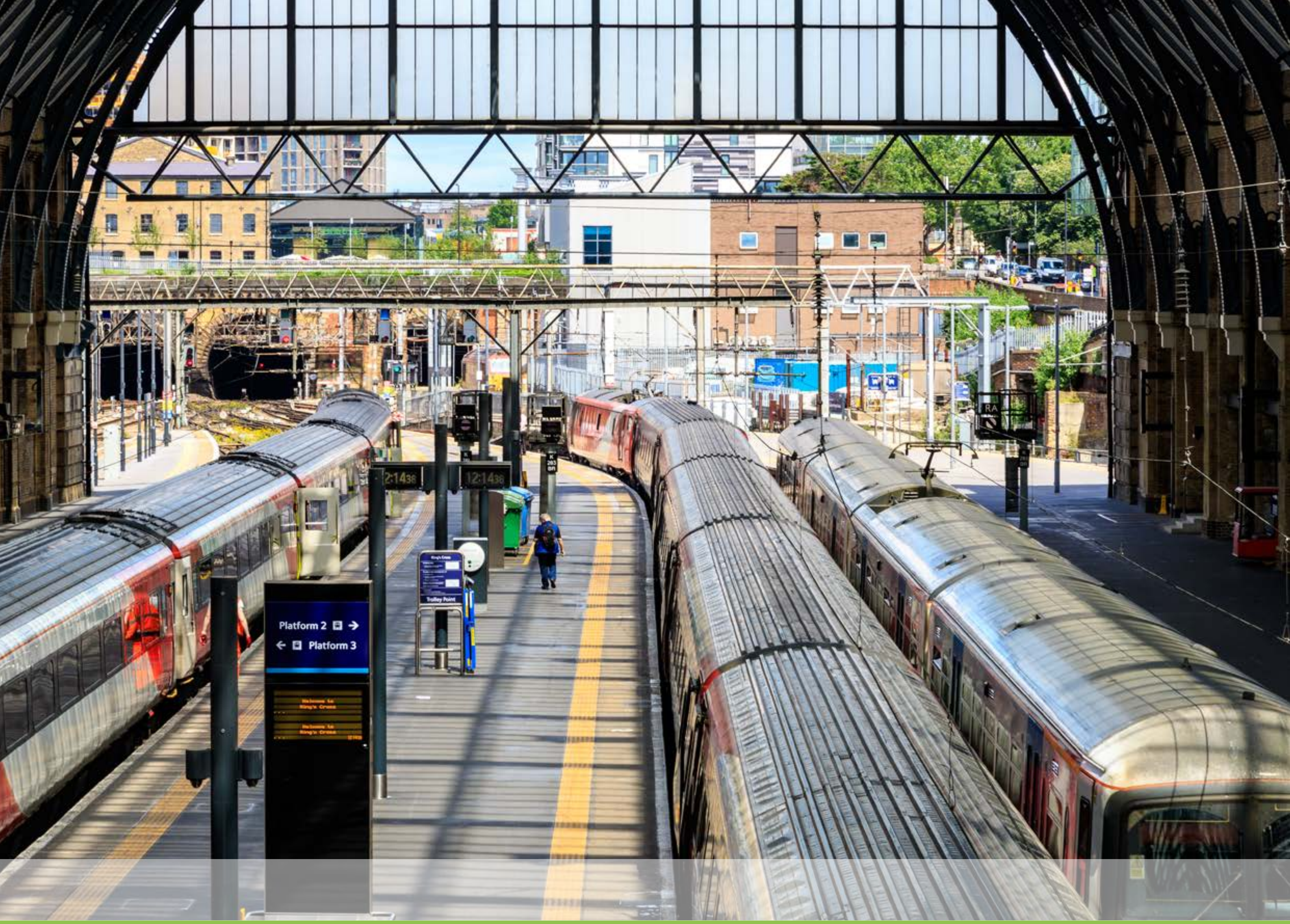

UIC SUSTAINABILITY

Noise from parked and stationary trains: An analysis of operational and technical solutions

Noise and Vibration Technical Advice (NOVITÀ) Project

February 2023

NOVITÀ
NOISE AND VIBRATION TECHNICAL ADVICE

UIC
INTERNATIONAL UNION OF RAILWAYS

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Foreword

Railways are committed to being part of the solution for a more sustainable future, for more liveable cities and for better public health.

The railway must become a better neighbour, and that means working hard to minimise noise and vibration.

No stakeholder can effectively address railway noise on their own, we can only make the necessary changes with all railway stakeholders working in close collaboration with each other.

With this new report, UIC, together with our members and partners, take a step forward to better understand the causes and issues arising from the impact of railway noise on people.

The study demonstrates continued improvement in this area and the power of exchanging ideas internationally.

My thanks and congratulations to all those involved in working in the Noise and Vibration Sector and Sustainability Platform at UIC and I encourage you to continue this important work.

François DAVENNE
Director General

1. Executive summary

Noise from trains at a standstill, in particular from parked trains, is still causing noise nuisance to lineside residents. With the ambition to be a caring neighbour, this particular situation causing noise on railways needs to be further considered and minimised in collaboration with all railway stakeholders. UIC, together with the members of the Noise and Vibration (NV) Sector, strives to raise awareness and exchange information among its members and other stakeholders, and advocates an international consideration of the issue. In this context, within the scope of the technical advice on noise and vibration (NOVITÀ) project, a study on noise from parked and stationary trains was initiated with the following objectives:

Establish a critical analysis of the current state,

- Develop a common understanding of the topic,
- Update existing literature information,
- Gather and analyse information on existing measurement data,
- Share the findings to the public

The main findings of this cross-national, multi-stakeholders' analysis are as follows:

- The entire railway sector, including infrastructure managers, railway operators, rolling stock manufacturers and policy makers are in agreement that noise from trains at a standstill has to be controlled and reduced through a combination of studies, action and future planning.
- A well-established and mutually agreed acoustic database is required to define limit values for noise from trains at a standstill and in particular from parked trains. It is recommended to prepare a dedicated measurement campaign for noise from parked trains based on a common approach to be agreed between the different stakeholders.

Alongside these findings, this report reveals that a range of mitigation measures are available and suggests two following relatively simple solutions for noise from trains at a standstill:

- The most efficient and effective implementation of the required standstill mode by the train driver should be monitored and supervised by team leaders and provided with training and incentives.
- Some other non-rail-based stakeholders (e.g., local authorities with regard to land use planning or regional authorities defining tenders for new rolling stock) seem to have either limited awareness of potential noise issues from trains at a standstill or do not have the prior experience or awareness to recognise them. Awareness raising could be targeted by collaborative dialogue, and tailored training could be provided. This is seen as one of the most effective ways to prevent potential problems and ensuring the quality of life of residents following activities beyond the control of railway stakeholders.

UIC Noise and Vibration Sector

NOISE & VIBRATION

2. Introduction

This scoping study deals with noise from trains at a standstill: There are two common situations where trains are at a standstill:

1. *Stationary train*: A train is waiting for a signal or stopping in a station during a commercial service. This situation and the corresponding noise is already well understood and addressed in regulatory frameworks, e.g. TSI NOI [1, 2].

2. *Parked train*: A train has completed its operational service and is being "parked" for an extended period of time in a depot or at a terminus of a line. This second situation has been observed to receive less attention from the authorities and less regulatory effort to prevent noise related to it. Therefore, the primary focus of the current study is noise from parked trains.

A technical report on noise from parked trains published by UIC NV Sector in 2014 [3] already detailed the importance of dealing with this topic: Due to urbanisation and increasing intensity of rail traffic, more and more people are potentially exposed to noise nuisance from railways. EU targets a further growth in rail traffic in order to reach the emissions targets of the green deal and the Paris agreement. Furthermore, modern rolling stock is equipped with a high number of technical components ensuring passengers' comfort and safet and, consequently, noise from parked and stationary trains pose an increasing risk of causing noise nuisance to neighbours of the railways.

Finally, the railway sector wishes to do its part in the European Commission's "Zero Pollution Vision", which aims to "reduce the share of people chronically disturbed by transport noise by 30%" by 2030 [4]. In this regard, the UIC NV aims to provide an essential contribution to the sector by launching a parallel scoping study on the nuisance and health impacts of railway noise with its members to analyse and compile data collected from relevant members [5].

Since the last UIC report, different stakeholders were working to progress the topic of noise from trains at a standstill, in particular during parking. Nevertheless, assessment methods and limit values for noise from parked trains have not yet been or have only been partially defined on an international, at least European level.

The study is addressed to different stakeholders such as railway operators, infrastructure managers, rolling stock manufacturers and policy makers but also the general public with the aim of further increasing and sharing knowledge of noise from trains at a standstill and in particular of preparing the way for a common understanding between the different stakeholders.

UIC NV Sector is particularly aiming to get an overview of current regulatory frameworks and standards, to collect measurement data and best practices about noise from trains at a standstill. The outcome of this project will be used to define further actions leading to less noise from trains at a standstill, in particular parked trains, such that railways will be accepted as desired neighbours in urban areas.


Vía
Via
PLATFORM
5

3. Why trains emit noise at a standstill

Rolling noise is the major source of railway noise in general. During standstill however, this type of railway noise does not appear, and the noise emitted by the various technical components of a train becomes dominant. The actual noise depends strongly on design parameters and the train and component operation scheme.

There are actually many reasons for trains to stand still: during commercial service, meaning with passengers on board, trains regularly stop in stations or at signals. In terms of noise, one generally refers to “stationary noise”, see the definition in chapter 5.1.1. Once taken out of service trains are usually parked for a certain time, e.g., overnight or during the week-end, before being put into service again, see definition in chapter 5.1.2. Typical parking locations are depots, but also stations and termini of secondary lines.

Figure 1 shows as an example the duration of different train operating modes of a regional train in Switzerland over a week [6]: parking phases are highlighted by black bars. Analysis from Switzerland found that regional and commuter trains are in average running 10 hrs per day in commercial service, so that standstill, in particular parking is the dominant operating mode during a day and potential noise issues related thereto should be taken seriously.

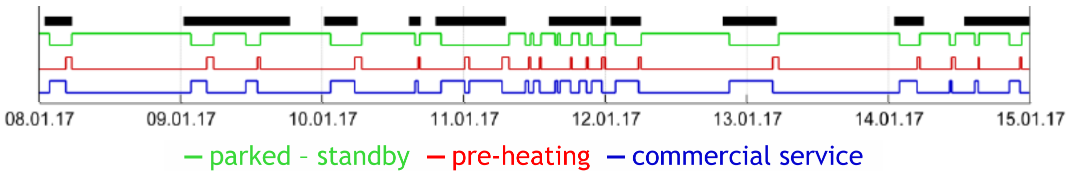


Figure 1: Operating modes of a regional train in Switzerland: low value = mode active – adapted from [6]

Trains generally emit noise when at a standstill due to the activity of the different technical components: stationary noise is generally louder in terms of overall and long term noise levels compared to parking noise, since the train is fully operational and all technical components are running to ensure traction (e.g. motors, power supply, converters), passenger comfort (e.g. HVAC) and safety (e.g. compressed air for the braking system). During parking the overall and long-term noise levels are generally lower than the stationary train mode, but intermittent or impulsive noise related to specific activities, e.g. brake or door tests, punctually running compressors, etc., are often found to be the reason for complaints from close-by residents.

When the train has completed its operational service, it is usually directed into a parking location. Once arrived at this location, the train is prepared to be partially or even fully shut down, mainly in order to save energy. During this phase, several technical components are switched off (e.g., engines) or put into an energy-saving mode (e.g., HVAC).

This is followed by the parking phase, which may include different modes: In some cases, only a few components are put into a reduced regime, for example, if the train is scheduled to be ready for service in a short time, if cleaning activities are carried out or if a certain temperature level must be kept (e.g. to prevent heating up during hot summer nights or to avoid damage to components due to freezing). This means that components run and emit noise either permanently, for longer durations or only from time to time (e.g., compressor). In other cases, the train is put into a more energy-saving mode for example during parking over the week-end. In this mode some components are still running, mainly to ensure protection of the technical components, e.g., frost protection of batteries. Nevertheless, noise is emitted by the train in this mode.

Preparation for service is the last scenario, where trains emit noise when at a standstill: During this phase the train is powered up, meaning that most or even all technical components are put back into normal service, e.g., starting of the traction system, air conditioning of the passenger area and safety-relevant tests such as brake tests are carried out.

4. Methodology

This report is based on three main inputs:

1. An online survey has been launched by UIC among infrastructure managers, railway operators as well as rolling stock manufacturers [7], [8].
2. A literature review focusing on laws, regulations, scientific and engineering publications has been carried out.
3. Acoustic measurement data from stationary and/or parked trains provided by UIC members has been collected.

4.1. Survey

UIC, in collaboration with VibraTec, launched an online survey entitled “Management of Noise from Parked & Stationary Trains for Infrastructure Managers and Operators” between October and December 2021. The survey is divided in four parts:

1. Regulatory framework
2. Complaints
3. Controlling parking noise
4. Measurement data collection

The survey was quite a success with in total 29 contributions, see Figure 2, which are shared as follows: 69 % of the participants are infrastructure managers, 24 % are operators and 7 % do both [7].

In order to provide a more comprehensive analysis of the noise issues related to stationary and parked trains and to better understand how rolling stock manufacturers are tackling this challenging issue, UIC consulted with UNIFE during the preparation of this report and requested consolidated feedback from its noise group [8]. Detailed information on manufacturers is not provided in this document.

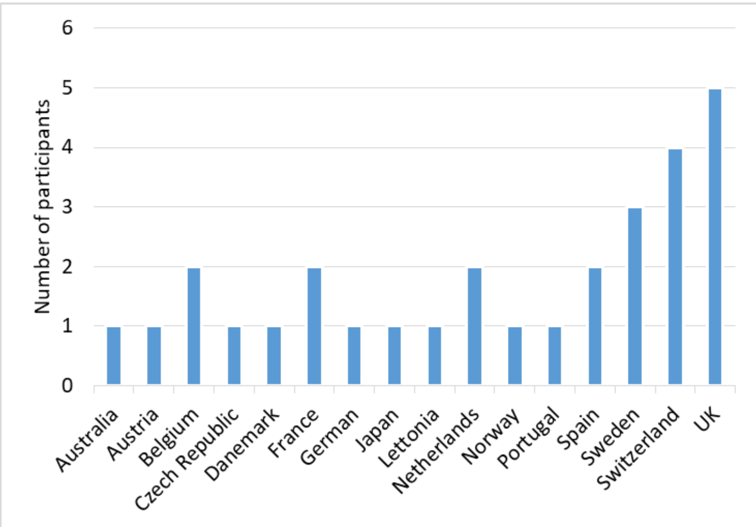


Figure 2: Origin of railway infrastructure managers and operators participating in the online survey

4.2. Literature review

Literature was provided by UIC members and VibraTec carried out a literature search additionally. The main focus was on literature after the publication of the last UIC report [3] on the topic, meaning after 2014. Two literature sources are of particular interest and mentioned thereafter:

- **Managing noise from parked trains – UIC report 2014 [3]**

  This first UIC report on the topic of noise from parked train summarises the current state in 2014, deals with legislations, lists mitigation measures and suggests guidelines to manage noise form parked trains. The report is based on a survey among UIC members and a literature review. Measurement procedures and methods are presented briefly.

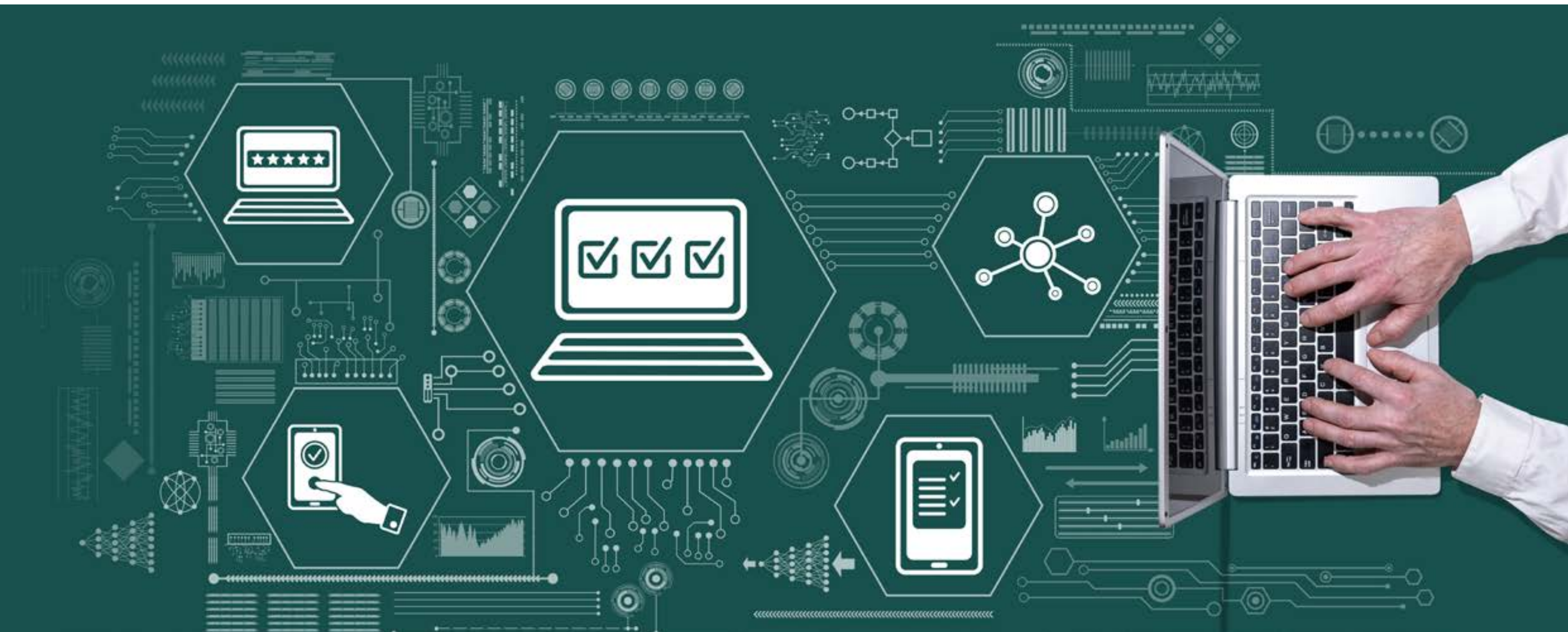
- **Assessment and limitation of noise from parked trains – EMPA report 2015 [9]**

  This report summarises a Swiss project on the assessment and limitation of noise from parked trains. The project aimed on establishing an emission database for each technical component in two different parking modes and to develop a noise assessment tool allowing to estimate critical noise distances according to Swiss law. The database is based on measurements following ISO 3095:2013 standard for stationary trains. Additional measurement positions are considered.

4.3. Measurement data

In total, 11 participants (7 infrastructure managers, 3 operators and 1 both) of the survey [7] provided acoustic measurement data from trains at a standstill. 41 % of the participants state that they do not have measurement data. The data provided by UIC members include:

- a large variety of rolling stock: from track machines to high speed trains,
- several operating conditions: stationary and different parking modes,
- different measured quantities, e.g. overall level and/or spectra based on varying measurement procedures, e.g. ISO 3095 positions or specific methods,
- data based on train or component level.



5. Descriptions and characteristics of train noise at a standstill

5.1. Descriptions

There are many situations where a train is at a standstill: e.g. in a station, at a red signal, during preparation for service or night time parking, etc. In all these situations the train may emit noise. For this study, a train at a standstill will be defined either as stationary or as parked. This is quite important, since legislation and regulatory frameworks may define different assessment procedures and limit values depending on the train operation when at a standstill.

5.1.1. Stationary train

The train is fully operational in that the pantograph is raised or the engine (electric or combustion) is running but the train is not moving, see illustration in Figure 3. Furthermore, the train is in commercial service with at least train personnel and eventually passengers on board. Stationary describes the situation of a temporarily stopped train, for instance, when the train is waiting for a signal, waiting to enter or leave a depot or maintenance yard, for trains stopped in stations or waiting to start the return trip at a terminus of a line. Generally, the train is ready to accelerate.

A number of railway technical documents and reports may have used a similar definition using the term "idling" for the description above, however, UIC, together with its NV sector members, has chosen to use the term "stationary" for the description of this condition, in connection with previous research carried out and published by UIC in the European region.

Noise emitting technical components of the train are in operation, for example, the engine, the air conditioning, heating, cooling or ventilation equipment (HVAC) may all be emitting noise. In the case of a careful vehicle design the noise-emitting assemblies and components may be set to a quieter operating mode, e.g. reduced fan speed.

Similar definitions are found in TSI NOI [10], in ISO 3095 standard [11] and its current draft for the upcoming revision [12].

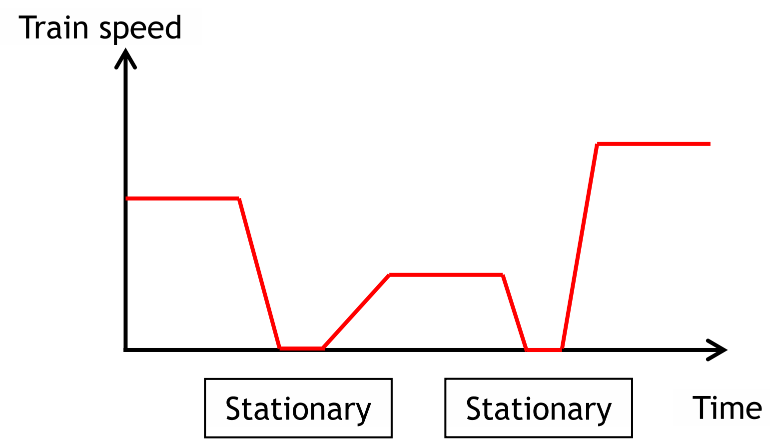


Figure 3: Definition of "Stationary train"

5.1.2. Parked train

A parked train is one that is taken out of commercial service for a longer duration at one place, e.g., in a depot, a maintenance yard, see Figure 4. No passengers are on board, however the train, depot, movement controller or cleaning and maintenance personnel might be present. This definition includes trains parked during the night at the terminus of a line.

A number of railway technical documents and reports may have used a similar definition using the term "stabled" for the description above, however, UIC, together with its NV sector members, has chosen to use the term "parked" for the description of this condition, in connection with previous research carried out and published by UIC in the European region.

Once the train has stopped at its location to be parked, parking can be split up into 3 phases:

- **Preparation for resting** – the train is at a standstill at the location where it is to be parked but technical components are still switched on (technical protection). This phase is similar to the definition of a "stationary train" but is different in the sense that the technical components will leave the full operation mode during this phase. This phase can take up to 30 minutes [9] and is mainly dominated by the noise from cooling systems of the technical components [13].
- **Resting** - the activity of the noise-emitting train parts are either temporarily, partially or totally turned down to save energy. Three different resting modes can be distinguished and described as follows:
  - Standby (preconditioning to achieve fast operational availability) means that some reduced power supply is sustained on the vehicle either by a raised pantograph, a running engine or generator or by a shore power supply and that some technical components may run in reduced operating mode [3], [14].
  - The sleeping mode aims at saving energy and reducing noise. Noise-emitting sources are either turned off or in a minimum noise configuration [3], [14]. More time is required to prepare the vehicle for commercial service compared to the standby mode.
  - Shutdown (entire and complete system shut down) where all noise-emitting elements are stopped and therefore quiet. The pantograph is lowered, and the engine is switched off respectively and none of the technical components is in operation. The mode is used for parking trains over a longer time period [14].
  - **Preparation for service** – re-starting up of technical components of the train including engine, traction systems, HVAC, ventilation systems as well as pre-heating or pre-cooling of the driver and passenger areas. This phase can take 15 to 30 minutes [9], but in some cases this can be longer, e.g., in severe winter or very hot summer conditions.

Currently a group of experts in CEN Group CEN/TC256/WG03 is working on a definition and assessment procedure for noise from parked trains. The results will be included in the upcoming new revision of EN ISO 3095 [12]; the resulting definition of the vehicle condition to be used for the assessment of noise from parked trains might be slightly different from the ones in this report.

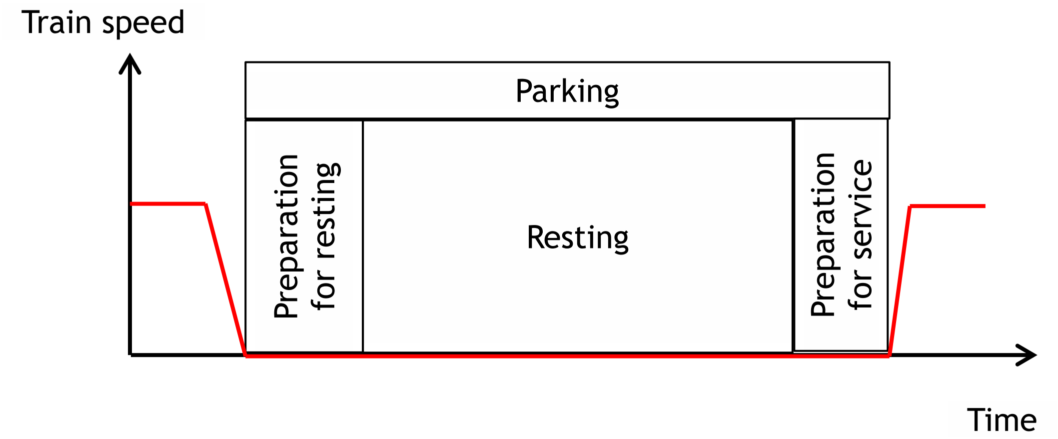


Figure 4: Definition of "parked train"

5.1.3. Emission and Immission (noise at a receiver)

Noise "*emission*" corresponds to the emitted noise of an acoustic source. Its sound power is an inherent property of the source and does not depend on the environment (weather, location, etc.). The emission characteristic of a technical component is usually determined on the train which thus includes installation effects, e.g., an underfloor component does not emit sound to the top. For practical reasons, sound pressure measurements are usually considered, and the assessment methods described in the ISO 3095 standard [11] are used in most cases. The sound power level of a component or a train unit can be estimated from the measured sound pressure values.

Environmental noise considers the effect of one or several noise sources at a receiver, e.g., on the exterior wall of a building. It therefore depends on the acoustic environment (e.g., weather conditions) and propagation path (e.g., obstacles). In some countries, the term "*immission*" is used to describe this situation. In the context of railway noise at a standstill one can assume

- point sources (e.g., one running component) with hemispheric sound propagation to the receiver. In free-field propagation, the major sound attenuation is obtained by the distance from the source: 6 dB are reached per distance doubling,
- line sources (e.g., several running components) with cylindrical sound propagation to the receiver. In free-field propagation, the major sound attenuation is obtained by the distance from the source: 3 dB are reached per distance doubling,

In practice, sound attenuations between 4 and 7 dB per distance doubling are observed [13].

Since most policy makers, see chapter 6.8, consider noise from a parked train as industrial noise, limit values and assessment are based on environmental noise methods. Typically, such an assessment requires knowledge of the following parameters of each noise source [9]:

- Emission characteristics, mainly sound power, spectral content and time pattern,
- Location of the source,
- Type of source for correction factors (monopole, dipole, directivity),
- Operating time and occurrence.

The most efficient way to reduce environmental noise from trains at a standstill is to reduce the emission at source level. This can be achieved by optimised operation schemes (e.g. low speed cooling fan) and/or acoustic design (e.g. low noise fan).

5.2. Characteristics of train noise at a standstill

The characteristics of noise from trains at a standstill depends on the train and the component's operating condition: Table 1 gives an overview of the different technical components and a qualitative estimate of their level of activity during different parking modes. The overview does not evaluate the noise generated by each component. The stationary train condition as defined in ISO 3095:2013 is taken as a reference for the activity during parking. The level of activity is described by the following symbols:

- (--) significantly less activity with short durations or continuous with low power,
- (-) less activity,
- (=) activity comparable to the stationary train condition,
- (+) more activity, in particular due to the fact that the train is not in a stabilised mode in contrast to the stationary train condition.

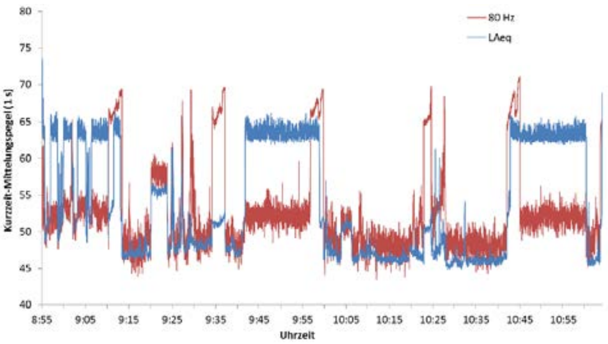
Concerning the preparation of resting mode, the activity of the components generally decreases during the duration of this particular mode (indicated by "= to –" in Table 1). For the preparation for service, the contrary is the case: activities grow during the duration of the mode and possibly reach levels above the stationary train mode, which is a stabilised mode in contrast to the preparation mode.

Component	Description	Preparation for resting	Resting - Standby	Resting - Sleeping	Preparation for service
HVAC (Passenger, driver)	Refrigerant compressor and condensor fan are the major noise sources. Cooling mode is generally the noisiest mode. Activity strongly depends on the climate conditions.	(=) to (-)	(-) Temperature thresholds in the passenger / driver area & for technical protection need to be respected	(-) to (--) Temperature thresholds in the passenger / driver area for train staff & for technical protection need to be respected	(=) to (+) Temperature level for commercial service has to be reached
Cooling fans/ pumps	Cooling supply for engines, generators, traction systems, etc. Fans are the most critical noise sources.	(=) to (-)	(--)	(--)	(=)
Air compressor	Supply of air for pneumatic systems (brakes, doors, pantograph mechanism)	(=) to (-)	(-)	(-)	(=) to (+) Possibly more activity if air tanks are empty
Air dryer	Drying of compressed air. Inevitable impulsive blow	(=) to (-)	(-)	(-)	(=) / (+)
Power supply (engine, generator, battery, pantograph)	Supply of power to technical components	(=) to (-)	(-)	(--)	(=) / (+) Possibly more activity in order to quickly provide energy to the train's systems
Transformers, converters	Supply of correct power input for components	(=) to (-)	(-)	(-) to (--)	(=)
Cooling systems for dining cars or freight wagons	Keep food and beverages at safe temperature	(=) to (-)	(=)	(=)	(=)

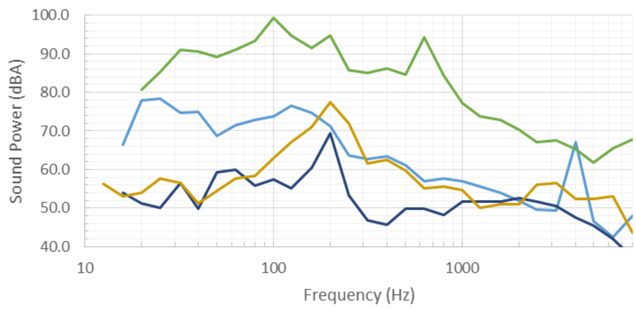
Table 1: Description of different technical components and their level of activity during different parking modes. Reference point for comparison: The level of activity in ISO 3095:2013 for the condition of stationary trains.

A stationary train is generally the loudest configuration of a train at a standstill: most critical noise sources are the traction system (engine, converters, transformers), cooling of technical components and HVAC systems, which generally run in continuous mode. In some cases, preparation for service might lead to more noise, since some components, e.g., compressors, might be more active compared to the stationary condition.

For parked trains (except for preparation of service) however, parts of the technical components, mainly the traction and HVAC systems, will be partially or completely shut down, which by consequence leads to less noise. In addition to that, most sources will operate in an intermittent manner, e.g., cooling or HVAC systems will be activated if a temperature threshold is violated and the compressor will run if the pressure drops below a minimum value, see Figure 5 left. Furthermore, noise characteristics can be broadband or feature tonalities, which can be highly annoying. Figure 5 right shows the sound power spectra of four cooling systems from different Swiss EMUs in resting mode “standby”: a large dispersion of the spectra is observed, which are related to the different sizes, operating points, and designs of the cooling systems.



Short time averaged level with microphone at X/Y/Z relative to the vehicle head 10.2 / 2.4 / 1.6 m



Sound power spectra of four different cooling systems in operating mode *parked-resting-standby*

Figure 5: Examples of measured data from parked trains (Swiss) – left: sound pressure level over time of a FLIRT regional EMU [9] – right: sound power spectra of cooling fans from different EMUs selected from calculation tool of [9], [15]

Participants of the UIC survey [7] were asked to judge the noise quality of the most critical sources:

Tonality: from 16 answers, 75% judged that tonal noise is significantly more critical compared to broadband noise (25%). This result requires more detailed investigation since no detailed definition of tonality or broadband noise was defined in the survey.

- **Frequency range** (Figure 6 left): the low frequency (< 300 Hz) range seems to be the most critical range. Nevertheless, the mid- and high-frequency ranges seem to be also quite critical.
- **Operation duration** (Figure 6 right): continuously operated components are the most critical noise sources.
- **Component location** (Figure 7): roof-mounted components are considered to be the most critical noise sources.

The UIC NV sector, together with its members, state that the results from this inquiry give only a first qualitative overview and should be handled with care, especially given that the survey did not include definitions of the critical sources that were indicated. In particular, the analysis in Figure 6 and Figure 7 should be extended to detail in order to identify which particular component and its operating mode is concerned by the mentioned critical noise features.

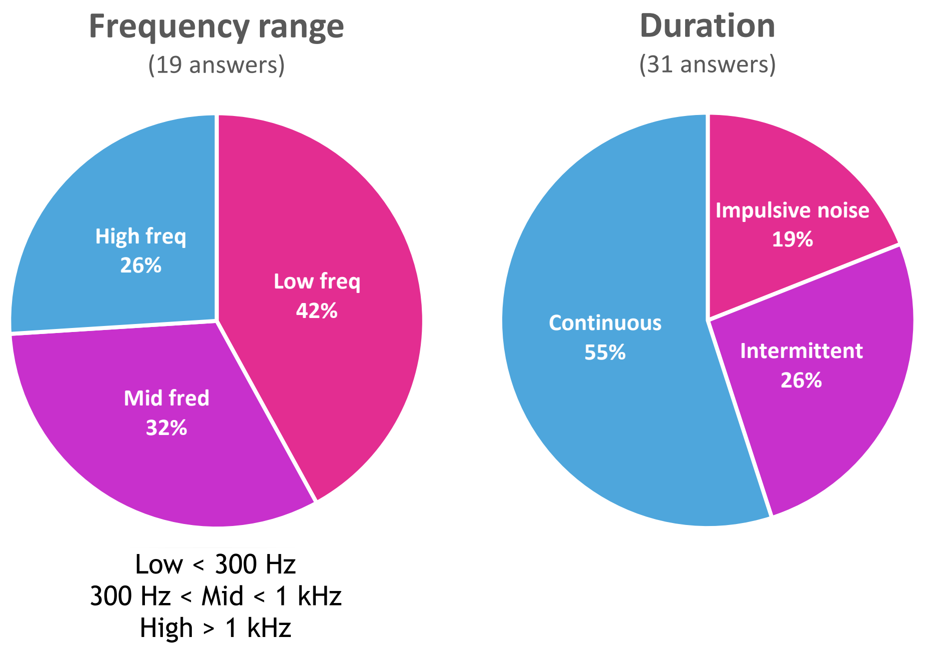


Figure 6: Characteristics of the noise from parked trains [7]

Finally, the following points are worth mentioning with regard to noise from parked trains:

- The very prominent occurrence of a series of impulsive noises is a main characteristic during preparation for service. These noises are related to the main switch, the rising of the pantograph for electrical units as well as main compressor activity due to brake tests [9].
- Some noise features are not directly linked to trains at standstill but appear nevertheless before and/or after the standstill phase when the train moves slowly, for example to be positioned at its parking spot. These features include brake and curve squeal, impact noise from rail joints, switches, and buffers, as well as low speed traction and rolling noise. They are related to moving trains and therefore they are not considered in this report.

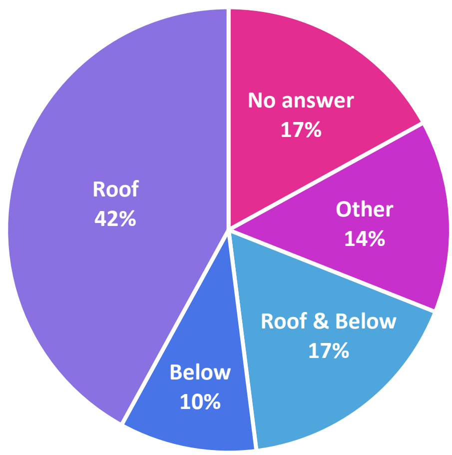


Figure 7: Location of the most critical sources on the train – 29 answers [7]

- The noise emission of a parked train may change over the course of the year due to different environmental conditions. This impacts the operating duration and occurrence as well as the power of the components [9].
- Alarm signals from horns or door systems are not treated in this report since they are safety-relevant, and their use can generally not be omitted. Another important finding of this study is that these issues are not dealt with in the TSI NOI, whereas noise emission from horns is regulated and prescribed in the TSI Loc & Pas and door warning signals in the TSI PRM. Furthermore, the NV sector members suggest that solutions could be offered to mitigate this matter by updating safety and operational regulations, such as performing the tests later in the day or selecting the area where the sensitivity is not high.

6. Regulatory frameworks and standards

Discussing documents such as regulatory frameworks, standards, and legislation about noise from trains at a standstill might be complicated for a non-expert reader for the following reasons [3]:

- Most documents deal with the same topic, but have different scopes: for example, the ISO 3095 standard "specifies measurement methods and conditions to obtain reproducible and comparable exterior noise emission levels and spectra for all kinds of vehicles operating on rails" [11]. Whereas the TSI NOI regulation for example specifies noise relevant limit values with the intention "to limit the noise emission of the rail system within Europe" [1].
- Documents refer either to noise emission or environmental noise (noise at a receiver or immission).
- Generally, each country has its own frameworks in particular for environmental noise (immission).
- Noise from stationary trains is usually considered as railway noise whereas noise from parked trains is often considered as industrial noise.

Furthermore, the main focus of existing regulatory frameworks, etc. is on noise from stationary trains. Even if noise from parked trains is a concern in many countries for a long time, only few regulatory documents on national or international level exist on the topic.

The following chapters 6.1 to 6.5 present a selection of documents in use to compose the regulatory frameworks dealing with noise emission from trains at a standstill. These are compared to each other in chapter 6.7. Finally, chapter 6.8 briefly deals with legislation.

6.1. ISO 3095:2013

The ISO 3095 standard [11] is the reference document for type testing of railbound vehicles in terms of noise emitted by railbound vehicles. The 2013 revision has a strong focus on testing TSI NOI parameters, see chapter 6.2. This means, that the TSI NOI relevant tests are described in detail and shall be carried out in all cases. Methods to assess parking noise are partially covered by the clause for “additional tests”. As this clause has been written to keep the standard open for additional interests, this clause is a lot less descriptive and does not include all information for carrying out a repeatable parking noise test. Nevertheless, the general information about measurement procedures and measurement positions is used as a basis for the evaluation of noise from parked trains in documents like the German VDV specifications [13] and EuroSpec [14]. Furthermore, the upcoming revision of the standard will consider parking noise in the same level of detail as the actual TSI NOI assessment for stationary trains, see chapter 6.6.

Chapter 5 of ISO 3095:2013 is dedicated to the stationary acoustic test: measurement and vehicle operating conditions are defined. The following points are worth highlighting:

- All equipment operates continuously at normal load at an external temperature of 20°C,
- The HVAC operating parameters are set considering the following assumptions: wind speed at 3 m/s, relative humidity at 50%, 700 W/m² energy from sun radiation and one person per seat.
- The traction equipment shall be in a stationary thermal condition with the cooling equipment working at minimum condition. Units with combustion engines shall be in idling mode.

Microphones are distributed around the unit at a distance of 7.5 m from the track centre and at a height of 1.2 m above the rail head, see Figure 8 (a reduced mesh is admissible, if the noise at a specific measurement position may be assumed to be the same as measured at another measurement position already included in the test). For low floor units or with roof-mounted equipment, a second measurement height of 3.5 m is recommended. The measured quantity is $L_{pAeq,T}$ with T at least 20 s or exceptionally 5 s, for example for intermittent sources.

A global noise indicator $L_{pAeq,T\ [unit]}$ for the unit under investigation is calculated from the individual measurement positions. However, only the measurement height at 1.2 m is considered in the basic TSI NOI test [1]. Tonalities may be assessed by the tonal difference ΔL according to ISO 1996-2 Annex C or DIN 45681:2005 standards. Assessment of impulsiveness, also optional, is defined in Annex A of ISO 3095:2013.

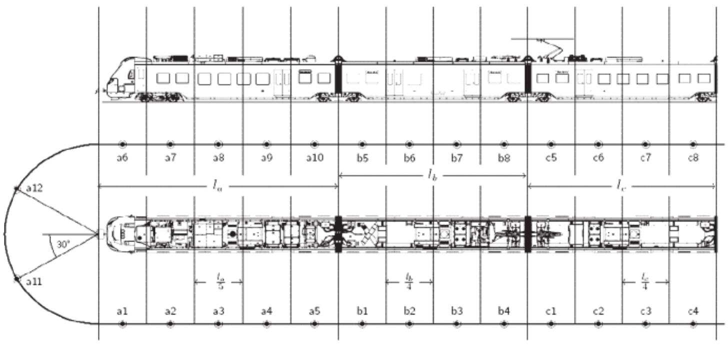


Figure 8: Measurement positions for stationary noise measurements according to ISO 3095 [11]

6.2. TSI NOI

TSI NOI regulation from 2014 [1] and its amendment of 2019 [2] specify noise relevant limit values with the intention "to limit the noise emission of the rail system within the [European] Union" [1]. For trains at a standstill, only the stationary, but not the parking situation is covered: sound pressure level limit values are specified for stationary noise under normal vehicle conditions at 7.5 m from the track centre at a height of 1.2 m above top of rail, see Table 2. Conformity has to be proven on three sound pressure values which are measured according to sections 5.1 to 5.5, 5.7 and 5.8.1 (clause 5.5.2 concerning the measurement height at 3.5 m is excluded) of ISO 3095:2013 standard [11]:

- $L_{pAeq,T\,[unit]}$: A-weighted equivalent continuous sound pressure level of the unit with T usually 20s.
- $L^{i}_{pAeq,T}$: A-weighted equivalent continuous sound pressure level at the nearest measuring position i of the main air compressor noise with time T being representative of one operating cycle.
- L^{i}_{pAFmax}: AF-weighted sound pressure level at the nearest measuring position i considering impulsive noise of the exhaust valve of the air dryer.

Section 5.4 of ISO 3095:2013 defines normal operating conditions, see previous chapter 6.1 of this report. The assessment of the main air compressor is addressed explicitly: "The train systems which are not needed for the operation of the compressor may be switched off to prevent contribution to the noise measurement. The demonstration of conformity with the limit values shall be carried out under the conditions solely necessary for operation of the main air compressor at the lowest rpm." [1].

Category of rolling stock	$L_{pAeq,T\,[=unit]}$ [dB(A)]	$L^{i}_{pAeq,T}$ [dB(A)] Main air compressor	L^{i}_{pAFmax} [dB(A)] Exhaust valve of air dryer
Electric locomotives & on-track machines with electric traction	70	75	85
Diesel locomotives & on-track machines with diesel traction	71	78	85
EMUs	65	68	85
DMUs	72	76	85
Coaches	64	68	85
Wagons	65	-	-

Table 2: TSI NOI limits for stationary noise assessed at 7.5 m from the track centre and a height of 1.2 m [1]

6.3. VDV - Technical note 1541

The association of German transport companies (VDV) published a document [13] summarising noise assessment methods and emission levels of modern EMU and DMU rolling stock for different parking operating modes, see Table 3. The publication and in particular the determined noise values do not claim to set binding requirements. Several acoustic indicators have been determined from measurements of a number of noise sources on different rolling stock. The measurements are carried out according to ISO 3095:2013 with microphone positions at 7.5 m from the track centre and at two heights above the rail: 1.2 and 3.5 m. Assessment of tonal noise (ISO 1996-2:2017, annex K is recommended) and impulsive noise is also addressed. Noise from alarm signals, door and brake tests is not considered. The following acoustic indicators are considered for the limit values:

- $L_{pAeq,K,T\ [unit]}$: A-weighted equivalent continuous sound pressure level of the unit with T equals 1 hour for the noisiest operating phase and energy-averaged over the unit's length and for both measurement heights.
- $L_{pAeq,K,T}$: A-weighted equivalent continuous sound pressure level at the loudest measurement position with T equals 1 hour for the noisiest operating phase.
- $L_{pAeq,T,Mot}$: A-weighted equivalent continuous sound pressure level at the loudest measurement position with running combustion engine. Time T has to be representative for the measured noise.
- $L_{pAeq,T,int}$: A-weighted equivalent continuous sound pressure level at the loudest measurement position for intermittent noise being longer than 3s. Time T has to be representative for the intermittent noise.
- $L_{pAFmax,imp}$: AF-weighted sound pressure level at the loudest measurement position concerning impulsive noise with a duration inferior to 3s.

Operating phase	Temperature range	$L_{pAeq,K,T\ [unit]}$ [dB(A)]	$L_{pAeq,K}$ [dB(A)]	$L_{pAeq,T,Mot}$ [dB(A)]	$L_{pAeq,T,int}$ [dB(A)]	$L_{pAFmax,imp}$ [dB(AF)]
Preparation for resting	-10 to 35°C	65	68	72	72	78
Resting in sleeping mode	-10 to 25°C	52	55	70	60	78
	25 to 35 °C Solar irradiation 700 W/m²	62	65	70	70	78
Preparation for service	-10 to 25 °C	65	68	72	65	78

Table 3: VDV maximum values for parking noise at 7.5 m from the track centre and heights of 1.2 and 3.5 m from the track centre [13]

Based on the consolidated answers of the UNIFE Noise group, as a result of the exchange of information between UIC and UNIFE in the context of this study, noise experts from rolling stock manufacturers recommended that the assessment methods suggested by VDV should not be followed. This is because they are too vague, in particular due to limited repeatability and comparability as well as insufficiently clearly defined operating conditions [8]. Nevertheless, according to noise and procurement experts from Deutsche Bahn, the specification was welcomed by rolling stock manufacturers at its publication and a joint revision has been proposed to edit out any lack of clarity.

6.4. EuroSpec

A group of European railway operators (SNCF, National Rail, DB, NS, ÖBB and SBB) jointly published a specification on parking noise for rolling stock with a focus on EMU [14]. The specification can be used voluntarily for tendering and verification with the aim of replacing individual company specific documents. It is considered to be an add-on to the TSI NOI and its aims are:

- gathering sound emission data to be used for environmental noise assessment (immission) in sensitive areas,

- minimising the noise of the train, since limit values, see Table 4, are defined for the loudest measurement position and not for the whole train or unit as in TSI NOI [1] (except for the air compressor which is considered separately in TSI NOI)

Rolling stock suppliers should provide detailed acoustic measurement data (sound pressure and sound power derived therefrom) for each single component for different parking modes. Assessment of tonal and impulsive noise is also addressed and should be assessed for each measurement position i, which is in contrast to ISO 3095:2013, where a single value for the entire unit under test is considered. The required measurement procedure mainly follows the ISO 3095:2013 procedure for stationary noise, specifies, however, the train operating modes in detail. If several sources are measured at one measurement position, the microphone should be placed 1 m in front of each source to characterise it properly. This may result in practice in an increased measurement effort compared to ISO 3095.

		continuous	intermittent	impulsive	impulsive brake test
Operating phase	V_{max} [km/h]	$L_{pAeq,T,i}$ [dB(A)]	$L_{pAeq,T,i}$ [dB(A)]	$L_{pAFmax,imp}$ [dB(A)]	$L_{pAFmax,imp}$ [dB(A)]
Standby	<250	64	58	75	80 / 90
Standby	≥250	67	62	75	80 / 90
Sleeping	<250	50	55	75	-
Sleeping	≥250	55	62	75	-

Table 4: EuroSpec limits at noisiest measurement position at 7.5 m from the track centre and heights of 1.2 and 3.5 m [14]

As for the VDV specifications, based on the consolidated answers of the UNIFE Noise group, noise experts from rolling stock manufacturers recommended that EuroSpec should be abandoned [8]. Railway operators and infrastructure managers, however, see it as a big step forward since single source data is necessary for environmental impact studies and thus improves the life quality of lineside residents. This issue will be reviewed at sector meetings with UIC NV sector members, and possible collaborations with UNIFE are intended, aiming to clarify open points.

6.5. New South Wales – Technical note

In New South Wales, Australia, noise from trains at a standstill (EMU, DMU, locomotives partially and passenger coaches) is regulated by a technical note [16] defining “minimum operating standards for rolling stock to operate on the TfNWS Metropolitan Heavy Rail Network”. The assessment of the rolling stock’s acoustic performance is based on the ISO 3095 standard. However, three standstill train modes are defined:

- Stationary mode 1: this mode is identical to the stationary mode of ISO 3095:2013 section 5.4.2 [11].
- Stationary mode 2: all equipment shall be configured to generate the maximum stationary noise of the vehicle with the engines at idle or running with minimum power required for ancillaries or battery charging. The following equipment should be considered for the maximum noise configuration:
- Heating, ventilation, HVAC, compressed air, brake systems, cooling fans, power converters, etc.

- Cyclic intermittent equipment including compressors, dyers and audible warning devices (except horns and emergency/warning alarms).

- Stationary mode 3 corresponds to parking in standby mode. The vehicle is temporarily out of service for daily cleaning and maintenance. Equipment is in minimal mode with typically low HVAC, power converters in general purpose outlet mode, etc. Cyclic intermittent sources including compressors, dryers and audible warning devices (expect horns and emergency/warning alarms) shall be included if they normally operate in this mode. Engines are shut down.

Microphones shall be positioned on both vehicles' sides at 7.5 m from the track centre and at both standard heights of 1.2 and 3.5 m; exceptions of ISO 3095:2013 are admissible. L_{pAeq}, L_{pAFmax}, L_{pFmax}, tonality, frequency spectrum and impulsiveness shall be measured. Tonalities and impulsiveness shall be assessed according to ISO 3095:2013.

Table 5 summarises the limit values for category C1 trains, which comprises EMUs. This category has the strictest values. The noise limit value is obtained by post-processing the $L_{pAeq,T}$ from each measurement position according to the procedure in Section 5.8 of ISO 3095:2013 [11]). It is thus a global value for the unit under test. L_{pAFmax} is the maximum measured sound pressure value from all positions.

Test condition	Metric	Noise limit [dB(A)]
Stationary 1	L_{pAFmax}	65
	$L_{pAeq,T\ (T \geq 20s)}$	62
Stationary 2	L_{pAFmax}	71
	$L_{pAeq,T\ (T \geq 20s)}$	65
Stationary 3	$L_{pAeq,T\ (T \geq 20s)}$	59

Table 5: Noise limits at 7.5 m from the track centre and heights of 1.2m and 3.5 m for standstill trains category C1 (EMU) in New South Wales, Australia according to [16]

6.6. Revision of EN ISO 3095

The CEN Group CEN/TC256/WG03 working group is currently preparing a revision of the EN ISO 3095 standard. A measurement procedure to determine noise emitted by a parked vehicle (light and heavy rail) is proposed [12].

The proposal defines the vehicle's conditions, including the operating mode (preparation for resting, resting and preparation for service) as well as climatic conditions depending on the climatic zone comprising winter and summer. Measurements shall only be carried out for the operating modes preparation for service and resting:

- Preparation for service means that the vehicle is preconditioning itself to achieve fast operational availability. The duration of this mode is determined by the time required by the HVAC system to achieve the target temperature inside the passenger saloon or driver's cab.

- Resting is defined as a long-term parking mode, e.g., during the night. Only components that prevent damage to the vehicle shall be active: Converters and transformers shall be set to minimum power, the HVAC is either set to minimum power or switched off, the vehicle is connected to an external power supply (catenary, third rail, shore supply).

For both operating modes two climatic conditions shall be considered: Night-time and winter as well as daytime and summer. External temperatures are defined depending on the climatic zone.

The measurement positions and general conditions are as defined in the current EN ISO 3095:2013 section 5 for stationary trains [11]. The measured acoustic quantities include $L_{pAeq,T}$ with T = 20 s plus additional quantities such as frequency spectrum, L_{pAFmax}, tonality and impulsiveness. The assessment of conformity of the vehicle under test is based on the evaluation of the energy averaged level $L_{pAeq,T}$ of all measurement positions and the position with the maximum value of $L_{pAeq,T}$.

Based on the consolidated answers of the UNIFE Noise group, this proposal is considered by the noise experts of rolling stock manufacturers as the preferred solution for the assessment of noise from parked trains [8]. The consolidated responses also indicated that some railway operators and infrastructure managers miss the option of measuring individual noise sources and the procedure of how these measurements should be carried out. Analysing the current situation by examining the answers of UNIFE's noise group, UIC NV sector members point out that the revision of ISO 3095 does not clearly explain this issue and therefore an additional document is needed to address it. In conclusion, the study recommends that railway stakeholders (rolling stock manufacturers, operators and infrastructure managers) should jointly carry out feasibility studies by exchanging information after the issues have been identified in order to most effectively reach agreement on the operating conditions of the train or component concerned.

6.7. Comparison of noise emission frameworks

The different regulatory frameworks and standards presented in the previous chapters cover all noise emissions from trains at a standstill: noise limits and assessment methods <u>for the stationary operating mode</u> are quite explicit. Table 6 summarises noise limits for stationary trains.

		TSI NOI	NSW
	Operating mode	Stationary	Stationary
$L_{pAeq,T,[unit]}$ [dB(A)]	continuous	65 (T = 20 s)	62 (T = 20 s)
$L_{pAeq,T,i}$	continuous	-	-
$L_{pAFmax,imp}$ [dB(A)]	impulsive	85 (Exhaust valve)	65 If impulsive: up to + 5 dB added to $L_{pAeq,T,i}$ according to particular procedure
$L_{pAeq,T,i}$ [dB(A)]	intermittent	68 (Main compressor)	65 (Compressors, Dryers)

Table 6: <u>Stationary</u> train noise limit values in dB for EMUs (V_{max}<250 km/h)

Assessment methods and train operating modes for noise from <u>parked trains</u> differ between the analysed frameworks as can be seen from the comparisons in Table 7 and Table 8. The propositions made in the revision of the EN ISO 3095 standard are seen by UIC's NV sector as a step forward in order to control and reduce noise from parked trains. Nevertheless, some aspects as the definition of operating modes, temperature definitions and a more detailed description of the measurement of single components are not satisfactory or missing. Evaluation of tonality and impulsiveness is unfortunately not harmonised between the different frameworks and countries, which is also criticised based on the consolidated answers of the UNIFE Noise group [8]. The UIC NV sector aims to conduct a follow-up study on this matter and to discuss it at forthcoming sector meetings.

	VDV	EN ISO 3095 revision Annexe G
Operating mode	Prep. for resting / service	Prep. for service
HVAC & meteorological conditions	Prep. for resting: -10 to 35 °C Prep. for service: -10 to 25 °C	Wind speed at 0 m/s Winter (central Europe): -10°C external temperature Summer (central Europe): 30°C external temperature Rel. humidity 60% 700 W/m² sun radiation
Other		For AC/DC vehicles, the AC mode should be considered. Hybrid, dual-mode, combustion or fuel cell-based vehicles should use an external power supply.
Measured quantity	$L_{pAeq,T}$, L_{pAFmax}	$L_{pAeq,T}$, $L_{pAeq,T,max}$, L_{pAFmax}
Evaluation	Unit, loudest source	Unit, car, loudest source, main air compressor
Measurement duration *T*	1 h	20 s
Measurement height [m] at 7.5 m from the track centre	1.2 3.5	1.2 optional 3.5
Tonality	ISO 1996:2:2007, annex K or DIN 45681:2005	

Table 7: Comparison of measurement and operating conditions to assess train noise for different preparation modes

	VDV	EN ISO 3095 revision Annexe G	EuroSpec		NSW
Operating mode	Prep. for resting / service	Resting - Sleeping	Resting - Sleeping	Resting – Standby	Resting – Standby (stationary 3)
HVAC & meteorological conditions	Standard: -10 to 25 °C Summer condition: 25 to 35 °C & 700 W/M² sun radiation	minimum power or switched off + Wind speed at 0 m/s Winter (central Europe): -10°C external temperature Summer (central Europe): 30°C external temperature Rel. humidity 60% 700 W/m² sun radiation	minimum power or switched off	maximum setting being available at train preparation under temperature ranges as defined in TSI CR Loc&Pas, clause 4.2.6.1.1	minimum power
Other	-	Components only active to prevent damage to the vehicle. Converters and transformers set to minimum power. Use of external power supply.	Converters and transformers set to minimum power	-	Converters in general purpose outlet mode. Cyclic intermittent sources included if they normally operate in this mode. Engines are shut down.
Measured quantity	$L_{pAeq,T}$, L_{pAFmax}	$L_{pAeq,T}$, $L_{pAeq,T,max}$, L_{pAFmax}	$L_{pAeq,T}$, L_{pAFmax}	$L_{pAeq,T}$, L_{pAFmax}	$L_{pAeq,T}$, L_{pAFmax}
Evaluation	Unit, loudest source	Unit, car, loudest source, main air compressor	Unit, all sources	Unit, all sources	Unit, loudest source
Measurement duration *T*	1 h	20 s	20 s	20 s	20 s
Measurement height [m] at 7.5 m from the track centre	1.2 3.5	1.2 optional 3.5	1.2 3.5	1.2 3.5	1.2 3.5
Tonality	ISO 1996:2:2007, annex K or DIN 45681:2005	-	ISO 1996:2:2007, annex K or DIN 45681:2005	ISO 1996:2:2007, annex K or DIN 45681:2005	Criteria per 1/3 octave band

Table 8: Comparison of measurement and operating conditions to assess train noise during different resting modes

Finally, limit values of noise from parked EMUs in different parking modes are compared in Table 9. A direct comparison between these limits is difficult since assessment conditions, e.g. measurement time, and evaluated values (unit vs. component) are different.

		VDV	VDV	EuroSpec	NSW	VDV	EuroSpec
	Operating mode	**Prep. for resting / service**	**Resting – Standby**	**Resting – Standby**	**Resting – Standby (stationary 3)**	**Resting - sleeping**	**Resting - Sleeping**
$L_{pAeq,T,[unit]}$ [dB(A)]	continuous	65 / 65 (T= 1 h)	62 (T = 1 h)	-	59 (T = 20 s)	52 (T = 1 h)	-
$L_{pAeq,T,i}$ [dB(A)]	continuous	-	-	58	-	-	55
$L_{pAFmax,imp}$ [dB(A)]	impulsive	78 / 78	78	75 (Except brake test) 80 (Brake test, 90 in Germany)	-	78	-
$L_{pAeq,T,i}$ [dB(A)]	intermittent	72 / 65	70	58	-	60	55

Table 9: Parking noise limit values in dB for EMUs (V_{max}<250 km/h)

6.8. National legislation

The UIC report on noise from parked trains published in 2014 [3] already summarised the situation and no major changes are observed since then. In this context it is worth to mention that national legislation generally focuses on the protection of the environment and people. This is one of the reasons why legislation is focusing on noise levels at a point of reception (immission) instead on noise emission from a particular source.

Furthermore, noise reception (or immission) is generally covered by laws and regulations on environmental noise, which distinguish between railway traffic noise applicable to stationary trains and industrial noise applicable to parked trains. In Germany, this has been clarified in detail by a decision of the Federal Administrative Court, which considers “only” the resting phase of a parked train, see Figure 4, as industrial noise. Preparation for resting or service is considered as railway traffic noise, which has less strict limits [17].

Noise limit values at a point of reception (immission) are usually based on different long term indicators such as L_{den}, L_{day} (usually 6 am to 10 pm), L_{night} (usually 10 pm to 6 am), etc. which are either determined in free-field conditions, on the building façade or even inside the building. Table 10 summarises noise reception (immission) limit values for residential areas within the EU, based however on data from the early 2000s. In general, industrial noise limits are significantly stricter than railway traffic noise limits, see Table 10. Since long-term noise values at a point of reception (immission) are not easily measured, they are generally assessed by calculation models which may differ from one country to another. Despite the different assessment methods, accurate input data is crucial for all models (sound power, operating mode and duration, etc.).

Railway traffic noise		
L_{day} [dB]	L_{night} [dB]	L_{den} [dB]
61 (55-70)	52 (40-65)	62 (55-73)
Industrial noise		
L_{day} [dB]	L_{night} [dB]	L_{den} [dB]
57 (50-70)	48 (40-70)	60 (46-76)

Table 10: Average noise limits at a receiver point (immission) for residential areas. Range of limit values are given in brackets. From [3]

In some countries (e.g., Sweden, Australia and the United Kingdom) the long-term values are completed by additional maximum noise level limits. Considering this limit makes sense since residents often complain about noise peaks [7].

6.9. European policy

Identifying noise limit values for parked trains is of importance for the European railway operating community comprising railway undertakings and infrastructure manager. The need for a definition of a harmonised maximum noise emission level is acknowledged at European level. Based on the consultation with the Community of European Railway and Infrastructure Companies (CER), the following aspects are highlighted by recommending the following consideration:

- The distinction between regulation at EU level for the sake of interoperability (TSI regulations) and regulation at national level for the sake of environmental protection and as input parameters for environmental noise prediction methods is well acknowledged and ensured.
- The respective TSIs will only indicate “Noise emission value indicator and limits of parked trains” whereas definitions and assessment method are described either in a harmonised standard published in the OJEU or in a harmonised standard referenced in the respective TSI.
- Setting noise emission limits of parked trains requires a sound analysis and assessment of compiled and meaningful data. The data collection and evaluation and the conclusions to be drawn from it shall be the subject of further discussions in order to specify:
  - a common measurement and assessment methodology,
  - the rolling stock to be considered in the analysis,
  - What to measure?
  - How to measure?

Considering these aspects is necessary in order to evaluate and assess noise from parked trains in the context of a future TSI Revision (i.e., between 2025 and 2027).

7. Noise data from trains at a standstill

7.1. Data collection and summary

Participants of the UIC survey [7] were asked to share measurement data from trains at a standstill. In total, 11 participants (7 infrastructure managers, 3 operators and 1 dealing with both) of the survey [7] provided measurement data from trains at a standstill. The data provided comprise different standstill modes and data from entire units (trainsets) or single components.

A statistically solid comparison between the different datasets is, however, not possible at the moment, for the following reasons:

- Different assessed quantities (e.g., per unit, per component, measurement positions, etc.) and post-processing (e.g., the estimation of sound power L_W from sound pressure L_p)
- Missing description of measurement conditions (e.g., measurement positions, environment, etc.). These conditions are however described in detailed measurement reports, which were not accessible within the present project.
- Differences and unclear description of train operating modes (e.g., parking, night time parking, energy-saving parking, etc.)

Nevertheless, the data provided allow different aspects to be illustrated and are a start towards a common database, which may be used to define future limit values. In the following chapters, some examples are shown with a focus on noise from parked trains.

7.2. Examples from the Swiss & Dutch database

The databases provided by Switzerland (with data from BLS, SBB and SOB) and the Netherlands (ProRail and NS) are used in these countries for systematic assessment of noise from trains at a standstill, e.g., environmental noise estimations in parking and depot areas. Both databases are based on sound power estimations from sound pressure measurements of single components. The measurements have been carried out by applying procedures similar to the ones described in ISO 3095:2013. It is worth mentioning that the Swiss database is publicly accessible [9], [15]. To a minor extent, data from Norway is considered, since one particular type of rolling stock is used in all three countries.

In the following subchapters the sound power of three different technical components is compared. The data provided has been processed for the comparison: A-weighting is applied and the operating modes are interpreted by the author of this report. The main purpose is to give a first insight into source levels and their variation; the analysis does not claim to be complete. A more detailed analysis, which could eventually lead to noise limit values regulations requires a more proper and careful assessment.

The analysis is carried out per train class; classes are defined by the type of commercial service:

- EMU Regional
- EMU Intercity: V ≤ 200 km/h
- EMU Highspeed: V ≥ 200 km/h
- Electric locomotive (E-loco)

and different operating conditions are defined, even if this is quite difficult from the information provided. A subjective interpretation by the author is used:

- Resting – Standby: standby if explicitly mentioned, but also high or full operating mode
- Resting – Sleeping: sleeping, sleeping at night if explicitly mentioned, but also low or energy-saving operating mode

7.2.1. HVAC

Figure 9 shows the overall sound power level of HVAC components for different train types:

- A large dispersion with a variation of up to 40 dB between the minimum and maximum value is observed within each vehicle class. This is due to the fact that different HVAC components and uses are included in the graph (passenger, driver and dining car units, cooling and heating mode, etc.).
- The sleeping mode has generally lower sound power levels compared to the standby mode which is expected.
- EMUs with higher speeds (Intercity & Highspeed) tend to have higher sound power levels in the standby mode compared to the regional type. This is probably related to a higher passenger comfort level and a more powerful HVAC unit at higher speeds.

It is evident from Figure 9, that a more detailed analysis is required in order to get a precise picture of the acoustic performance of the HVAC component.

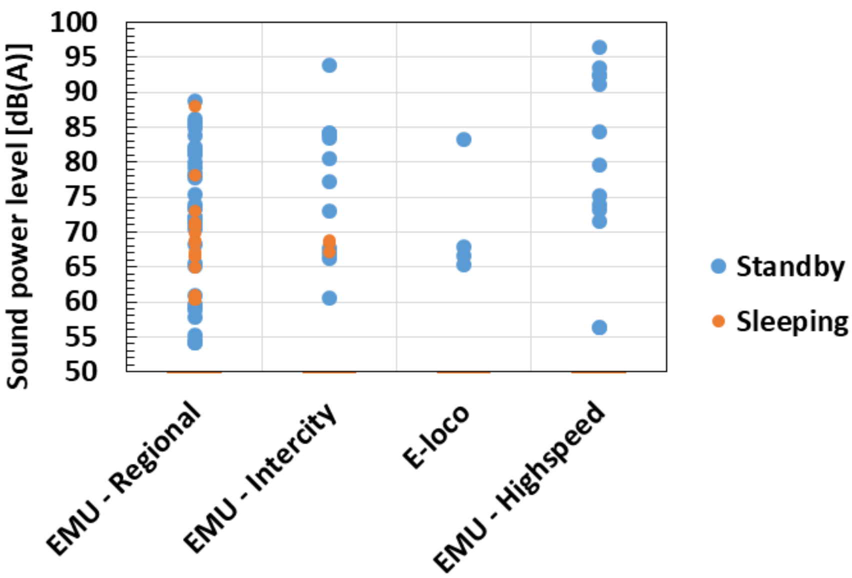


Figure 9: Sound power level of HVAC components

Figure 10 is a first try in this sense: It details the sound power level of the HVAC type (left driver's cab vs. passenger area) and the HVAC mode (right: cooling vs. heating) for EMU train types:

- Passenger HVAC systems tend to have higher sound power levels, which is probably related to their larger size and higher performance.

- No clear trend is visible for the comparison between the cooling and heating mode, which requires more detailed analysis since exterior temperature conditions are not included in the analysis.

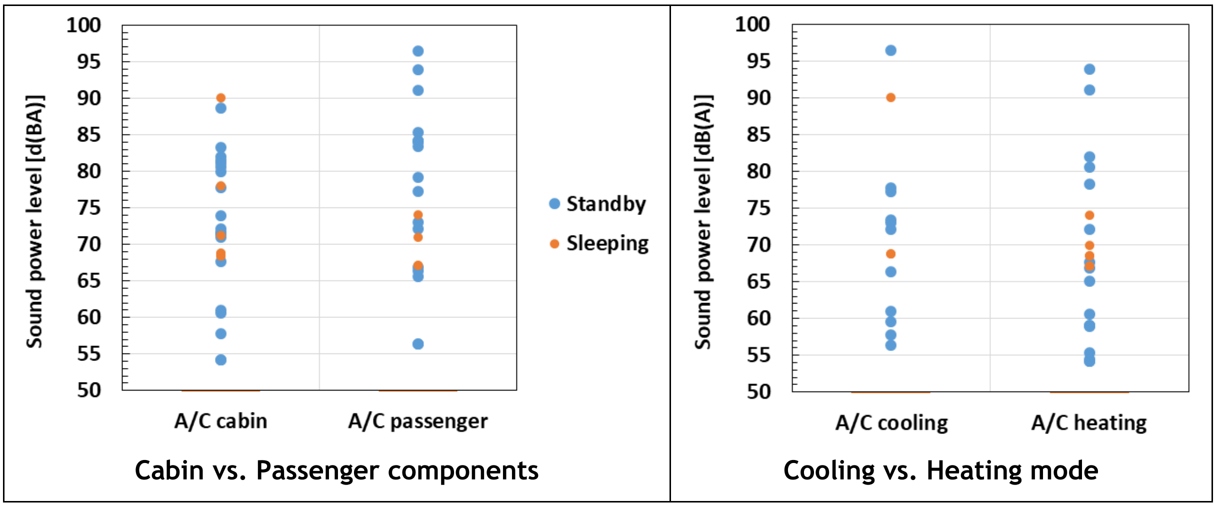


Figure 10: Sound power level of HVAC components of EMU train types

The examples in Figure 9 and Figure 10 show that for the HVAC component, sound power differences between the rolling stock type and the application / operating mode exist. According to UIC's analysis, further investigation is required, in particular if any relevant noise limit values should be determined (see the conclusion in chapter 7.5).

7.2.2. Compressor

Figure 11 shows the overall sound power level of compressor components, which comprise auxiliary and main compressors located on the roof or under the train, continuous operation, and pressure valve releases as well as standby and sleeping modes:

- As for the HVAC component, see chapter 7.2.1; a large dispersion is observed within each vehicle class, illustrating that further analysis is necessary in order to get a more precise picture of the acoustic performance of the compressor component.
- The levels for the sleeping mode are generally lower than the ones of the standby mode.

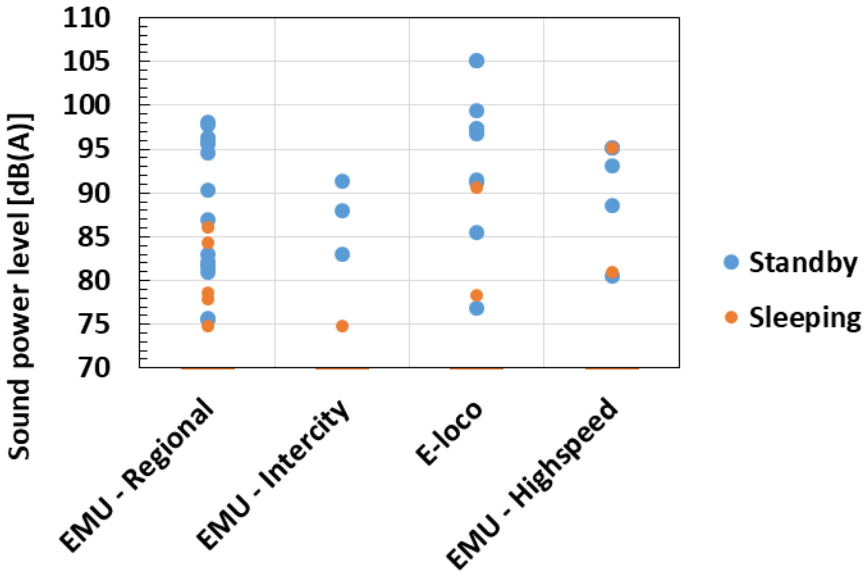


Figure 11: Sound power level of compressor components

7.2.3. Cooling systems

Figure 12 presents the overall sound power level of cooling system fans, which comprise cooling systems of the transformer, traction unit, inverter, batteries, etc. as well as standby and sleeping modes:

- As for the previously analysed components, a large dispersion is observed for the cooling fan component requiring further analysis to get a more precise picture.
- The levels for the sleeping mode seem to be similar to those for the standby mode, which might be a hint that fans rotate at the same speed for both operating modes.

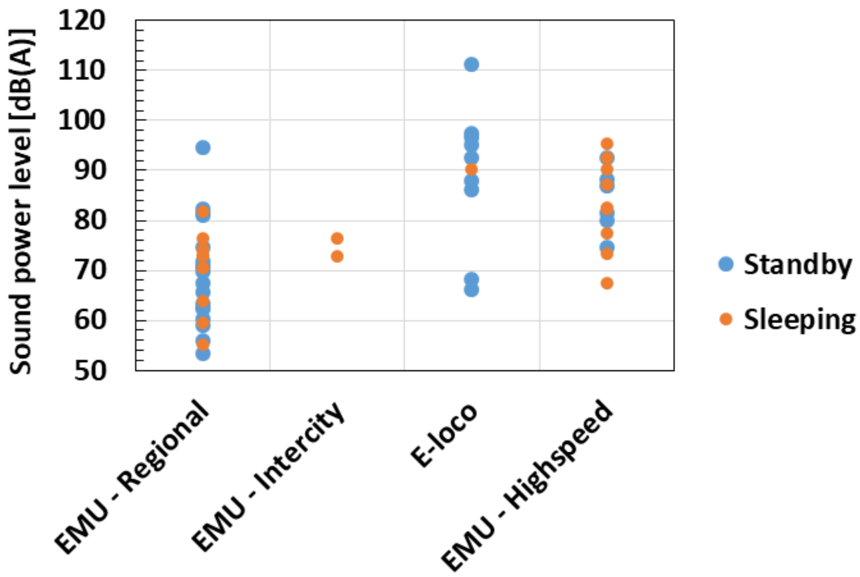


Figure 12: Sound power level of cooling system fans

7.3. Older versus modern rolling stock

Modern rolling stock, in particular EMUs, are typically equipped with more technological components than older rolling stock: this is explained by a demand for more technological features, the integration of technical components within the EMU (e.g., motors and traction equipment were concentrated on the locomotive in the past), an increased concern for safety as well as passenger comfort. At first sight, this might increase noise from trains at a standstill. However, noise emitted by technical components has been significantly reduced since with technological advancement and the implementation of tighter specifications. This is illustrated exemplarily by three examples extracted from the data provided by NS/ProRail (NL), SBB/BLS (CH) and Transport for NSW (AU). For each type of rolling stock, the first year of production / service is indicated. Some of the rolling stock might be retrofitted during the mid-life overhaul. Furthermore, according to the survey's outcomes, UIC NV sector agreed the following analysis should be interpreted with caution, since in some cases the operating modes, the electrical or mechanical power of the equipment, etc. may not be comparable. This outcome indicates that further investigation, beyond what was conducted in this study is necessary.

Figure 13 shows the sound power levels of three technical components of two generations of Regional and Intercity EMUs in the Netherlands. The operating mode is resting – standby, except for certain components, where "high" and "low" is indicated: high corresponds to a normal operating mode during preparation for service or in service; low corresponds to the resting – standby mode. For the compressor and auxiliary converter, the sound power level decreased significantly for the modern EMUs. The HVACs of the modern EMUs seem to be more silent. For the *Intercity 1996* it is worth mentioning that the original HVAC was replaced by a heat pump, which significantly reduced noise.

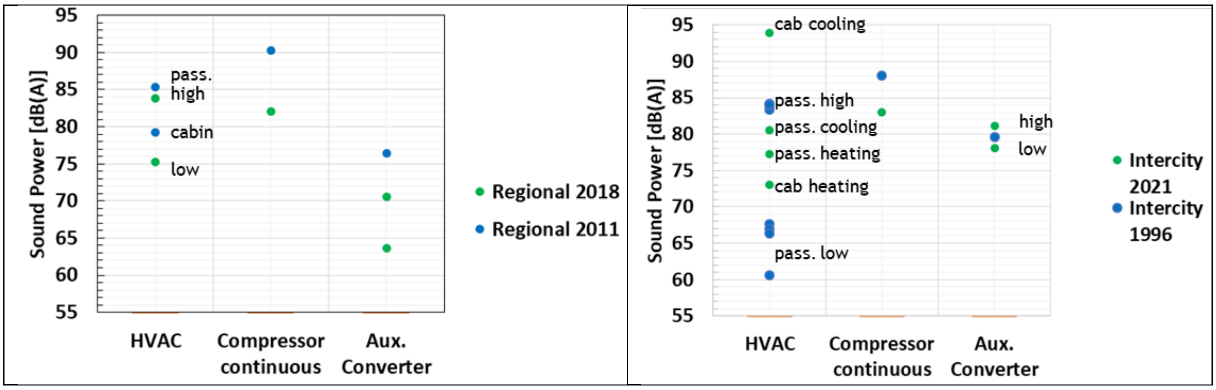


Figure 13: Comparison of component sound power levels between older and modern rolling stock – operating mode: resting – standby - data provided by NS / ProRail (NL)

Figure 14 compares the sound power levels of different HVAC components / operating modes of three generations of EMUs of the same rolling stock class used in Switzerland for the resting – standby operating mode. The sound power level for the more modern rolling stock slightly decreases. It is worth mentioning that the *1998* and *2008* rolling stock are based on similar architecture.

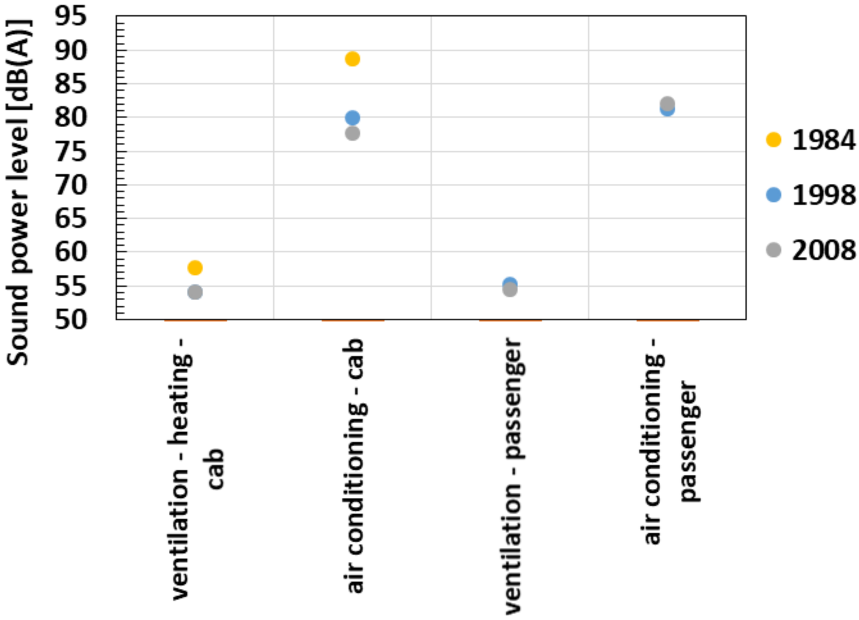


Figure 14: Comparison of HVAC components between older and more recent rolling stock - operating mode: resting – standby – from Swiss database [15]

Finally, Figure 15 compares the sound power levels in the resting – standby operating mode of three technical components of four generations of suburban double decker EMUs in Australia. The presented data were collected over the years by Transport for NSW from different parking noise assessment projects. Generally, the more modern types of rolling stock, except the EMU 2021, seem to have a better acoustic performance, in particular for the air compressor. For the HVAC, two values are given for each EMU, except the one from 2002, which are not further detailed in the data provided.

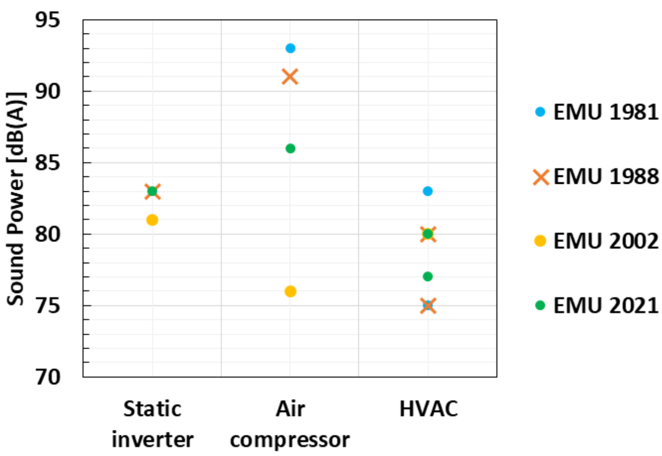


Figure 15: Sound power levels of different components of 4 generations of EMU in operating mode: resting – standby – data provided by Transport for NSW (AU)

7.4. Variability of noise from one source

Figure 16 shows measured sound pressure levels of two HVAC types from a double-unit Regional EMU. The data was provided by ARUP (UK) and measurements were made at a distance of 1 m on-axis from the HVAC fans. These were operating at a constant speed in the heating mode and correspond to a train preparing for resting. A significant variability in terms of sound pressure level is observed with standard deviations of 0.7 dB (above cabin) and 2.1 dB (above the door) respectively.

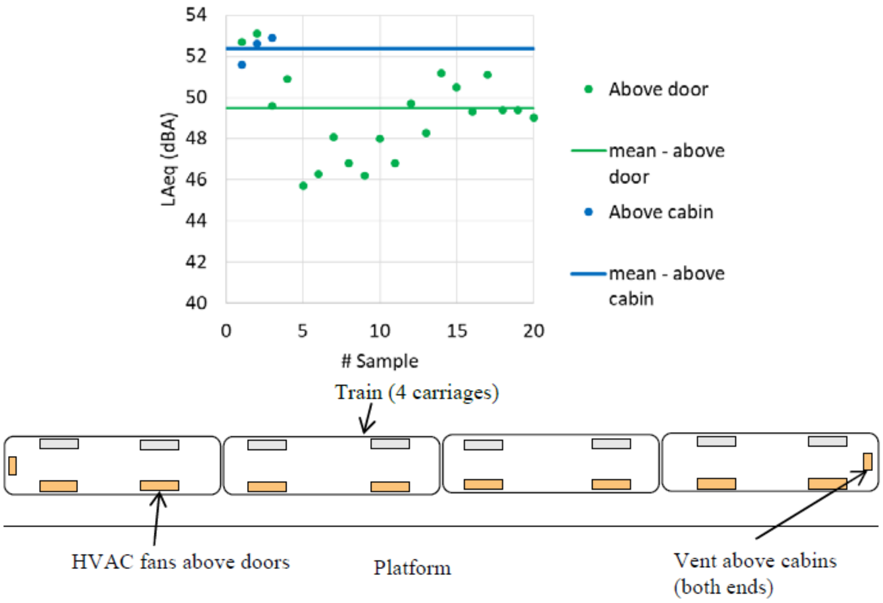


Figure 16: Sound pressure LAeq of two HVAC types (above door, above cabin) measured on the same train – linear mean value - data provided by ARUP (UK)

Another example of component noise variability is given in Table 11. In this case several units of two different STADLER FLIRT EMU classes were characterised [9]: Each source was operated individually, meaning that the operating mode is not representative of a particular standstill mode. The standard variation is globally around 2 dB, which might not only be related to differences between the trainsets, but also to measurement variations.

	STADLER FLIRT class 521			STADLER FLIRT class 522			Total		
	Energy averaged mean	Standard deviation	Samples	Energy averaged mean	Standard deviation	Samples	Energy averaged mean	Standard deviation	Samples
HVAC cab	61.9	0.8	3	-	-	-	61.9	0.8	3
HVAC passenger	53.2	0.7	2	55.0	2.5	5	52.7	2.1	7
HVAC passenger + compressor	56.3	3.1	2	57.3	1.3	2	55.0	2.1	4
Compressor	52.5	1.1	4	55.7	1.2	3	55.4	2.0	7

Table 11: Variability of measured sound pressure levels (dB(A)) of two different STADLER FLIRT EMUs class – Microphone at 7.5 m from the track centre at a height of 1.2 m – from [9]

7.5. Conclusion

A great number of measurement data from trains at a standstill has been succesfully collected as part of the one-year desktop research initiated by UIC as a preliminary study [7]. The analysed data showed a large variability between components, operating modes and train types, which is on the one hand due to limited comparability of the data itself (different measurement procedures, component operating modes, etc.) but also due to inherent technical differences of the characterised object (train type, design of the component, etc.)

The analysis showed by consequence what is needed in order to establish a state–of-the-art database on noise from trains at a standstill, in particular parked trains. A common understanding / definition of the following items is required:

- Measurement procedure, e.g., this can be based on the ISO 3095 standard,
- Measurement quantity and assessment thereof,
- Categorisation of components, e.g., all HVAC components in one group or separation into passenger, driver, etc.
- Operating points, e.g., sleeping mode, heating / cooling mode, etc.

Establishing such a database, especially with the goal to suggest TSI NOI limit values at train or component level for parked trains, requires a systematic and common effort by all concerned stakeholders, especially operators, train owners and rolling stock manufacturers.

As an outcome of this study, UIC highlighted the following aspects that should be considered:

- The existing database can be used as a starting point by analysing in detail the measurement and operating conditions. It is probably reasonable to limit the database to the most recent rolling stock, where the measured data is relatively recent, and persons involved may still have the measurements in mind. Even with this restriction, it can be expected that this work is relatively demanding and that, in the end, the data can only be compared to a limited extent. Nevertheless, this would be useful for defining a dedicated measurement campaign.
- A dedicated measurement campaign with a focus on the most common rolling stock within the European market can be launched. However, those managing the measurement campaign should consider that different types of rolling stock from the same product family might be equipped with very different components and that there may be differences in operating schemes from one operator to the other.
- Rolling stock manufacturers should be involved in the development of the state-of-the-art database, since they might already have relevant data available, so that a holistic approach can be taken to noise reduction on standstill trains.

8. Noise complaints related to trains at a standstill

8.1. Examples from the press

Noise complaints related to trains at a standstill are regularly reported in the press. Some selected and collated news are shared below, in order to illustrate the diversity of complaints, however these examples are limited in representing the real scenario and UIC, together with its members, recognises the growing number of complaints:

- Residents of the Malakoff quarter in Paris, which is located close to the tracks of Montparnasse station, complain about noise from TGV trains that are stationary for a while. Noise from engine cooling systems located at the upper side of the TGV power cars are the main reason for the annoying disturbances. Sound pressure levels of up to 80 dB (L_{Aeq1s}) are observed at a measurement station installed at a distance of 100 m from the tracks on a residential building [18], [19].
- Close to Chartres, France, train maintenance in a railway depot causes nuisances to residents since 2016. The tracks are slightly elevated in such a way that they are at the height of residents' living rooms. Complaints are mainly related to idling diesel engines of trains which are prepared for commercial service. According to SNCF current noise legislation is respected [20].
- In Düsseldorf-Eller, Germany, residents living close to an overnight parking area of passenger trains , see Figure 17, complain in particular about engine and fan noise from EMUs. [21].

Figure 17: Parked trains in Düsseldorf-Eller, Germany (® Andreas Endermann, Rheinische Post, [21])

- In Deisenhofen, Germany, citizens founded a local noise protection initiative (ILI) following the introduction of a new rolling stock, which caused noise complaints during night-time parking. Several mitigation measures were implemented in cooperation with Deutsche Bahn: the relevant components were equipped with silencers and selected citizens were trained to become "noise detectors" reporting noise anomalies to Deutsche Bahn [22].
- In a relatively loud (road, rail and tramway traffic noise) residential area, near Den Haag, Netherlands, residents complain about noise coming from nearby electric locomotives parked overnight. The continuous, loud, and insistent humming noise is related to the air conditioning system. As a solution it was agreed not to park the locomotives in the area [23].

8.2. Results from the survey

The survey [7] conducted in the context of this report allowed to quantify issues and complaints of noise from stationary, and in particular parked trains:

- About 25 % of the participants never experienced issues with noise from stationary or parked trains. It is worth reminding you that a large majority of participants are infrastructure managers (69 %).
- Complaints about noise from parked trains increased for 45 % of the participants over the last five years, whereas as 38 % did not observe any change, see details in Figure 18. Among the reasons for the increase, participants list a larger number of trains, new maintenance facilities, less noise tolerance by residents, more residences close to railway tracks and modern trains with more components than older ones. A more detailed study may be required due to the diversity of responses.
- The highest criticality with regards to parked train noise is from locomotives and DMUs, see Figure 19. EMU trains have an intermediate criticality, whereas passenger coaches and freight wagon have a low criticality or even do not cause issues. The category "other" may include on-track machinery, also called "yellow vehicles", which are not further analysed in this study and may require further investigation.

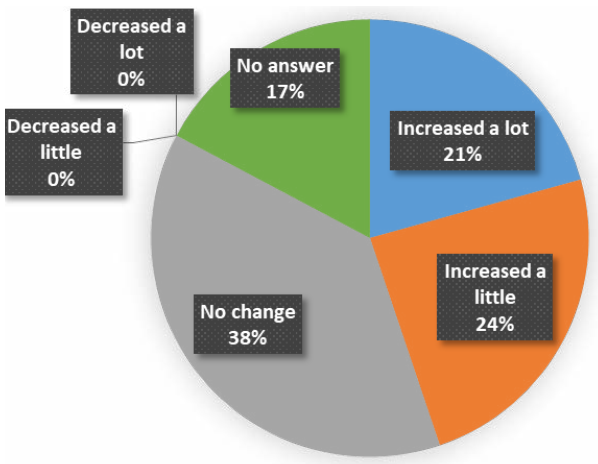


Figure 18: Evolution of complaints related to parked train noise during the last five years – UIC survey [7]

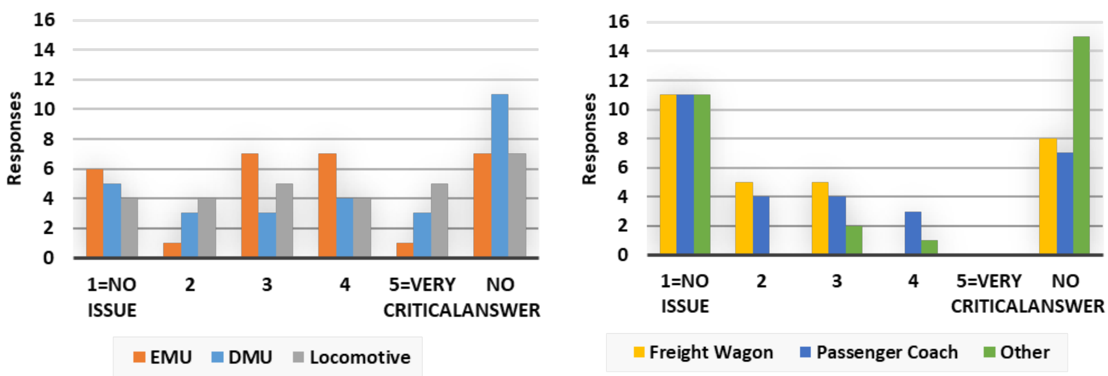


Figure 19: Criticality of rolling stock with regards to parked train noise

Participants of the survey highlighted in the comments section the following main reasons for noise complaints from parked trains, see also Figure 20:

- **Densification & Lack of space**

  The challenge or risk of finding available space to park more trains despite growing network capacity and/or rising urban densification close to shunting yards, railway depots and stations.

- **Engine running & night-time activities**

  Running engines (e.g., old rolling stock with problems during restarting), punctual engine starts to prevent power downs, cleaning activities and low speed train moving operations are cited among the reasons for complaints.

- **Roof mounted sources & HVAC**

  Generally, complaints are related to fan noise from roof mounted sources, e.g. power converters or HVAC units.

- **Preparation for service**

  Complaints are related to engine starts in particular from diesel engines, air and temperature conditioning and different tests (brake, horn, doors).

- **Less noise tolerance**

  People are increasingly less tolerant of transport noise including railway noise. Media coverage of the parking noise problem increased people's awareness leading consequently to more complaints, but the further investigation needs to be done on perceptions by exploring the root cause of complaints.

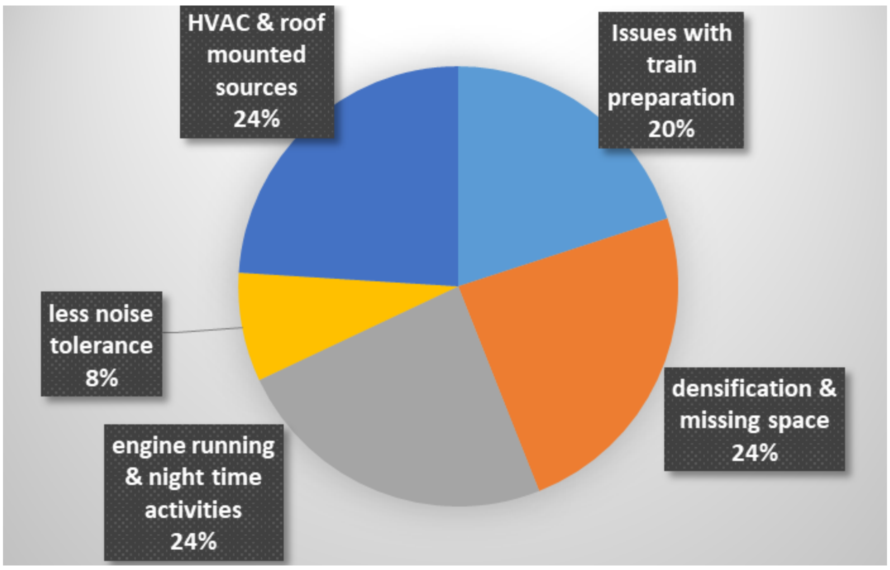


Figure 20: Reasons for noise complaints regarding parked trains – 25 answers, multiple answers possible - [7]

9. Noise management practices – noise mitigation solutions

Noise nuisances for residents can be reduced in many different ways and involve questions of technical feasibility, costs and legal requirements. Figure 21 summarises different mitigation measures taken by the participants of the UIC survey in order to combat parking noise issues; measures against noise from stationary trains were not addressed by the survey.

The following chapters give details of some mitigation measures. It is worth mentioning that some measures require cooperation between different stake holders, e.g., infrastructure managers and operators, but in some cases rolling stock manufacturers should also be involved in seeking solutions.

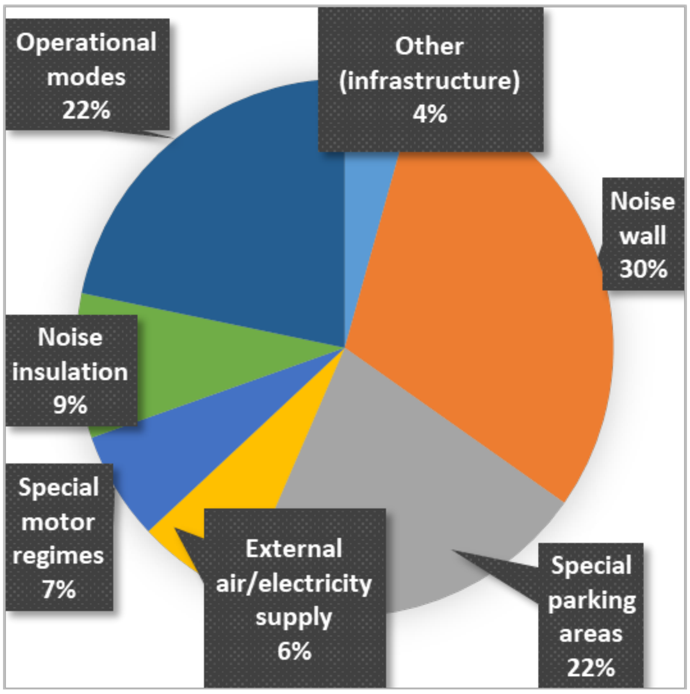


Figure 21: Parking noise mitigation measure (46 answers) – from [7]

9.1. Noise mitigation measures on the vehicle

One of the most important ways to effectively reduce noise from trains at a standstill is to directly act on the rolling stock, since this means directly acting on the source of the problem: this means either manufacturing quieter trains or introducing upgrades or retrofits during overhaul operations on existing rolling stock. Even if technical solutions exist to reduce noise from technical components, they generally generate higher costs, require changes in design procedures or even require a new homologation in the case of retrofitted trains.

According to some participants of the survey [7], rolling stock manufacturers do not play a steering role in manufacturing more silent trains unless there are stricter legal requirements, and/or ordering parties/purchaser define tighter requirements. As mentioned in Chapter 10.2, in some cases the local authorities that purchase the trains and are not the railway operator or infrastructure manager should also consider their role in addressing the noise problem. In these cases, rolling stock manufacturers are also expected to take on the role of guiding local authorities in contributing to the mitigation of nuisance due to noise on the railway.

The EuroSpec specification [14], see chapter 6.4, currently used for procurement by DB, NS, SBB and SNCF, aims to define stricter limits and to clarify the assessment procedure. However, as described in Chapter 6.3 and Chapter 6.4 UNIFE's consolidated answers from its noise group state that current specifications, in particular VDV [13] and EuroSpec, lack precision and repeatability. This is thought to be due to the fact that rolling stock manufacturers find it difficult to predict parking noise during the train design process because the definition, evaluation and train operating conditions are not well defined [8]. Therefore, the different stakeholders need to work together from product development to the solution of after-sale issues that occur during the operation period.

VDV Technical Note 1541 [13], see also chapter 6.3, lists the following items aiming at less noise during train standstill:

- Design of technical components:
  - Use of noise optimised components such as fans with spherically orientated blades or screw compressors,
  - Acoustic encapsulation of noisy components or use of acoustic screens (also suggested in [24]),
  - Arrangement / positioning of noise emitting components on the train,
  - Orientation of exhaust flows (e.g., along the train axis),
  - Use of silencers for exhaust valves,
  - Thermal insulation in order to reduce the requirement for heating / cooling in the driver's cab or the passenger coach: tinted window glass, sun reflection films, automatic sun protection curtains in the driver cabin,
  - Use of the air circulation mode for cooling / heating purposes.
- Software:
  - Control possibilities for demand-controlled operation during parking (energy- and noise optimised parking),
  - Reduction of the occurrence and duration of component activity: optimised coasting of cooling systems after shutdown of traction and power supply systems, HVAC with low fan speed,
  - Demand-controlled interior temperature,
  - Implementation of optimised train operation configurations (energy-optimised parking, cleaning, etc.) with 1-button activation,
  - Support for staff via Human-Machine-Interfaces.

A technical note [6] by the Swiss Association for Public Transport proposes an energy-optimised parking mode that is close to shutting down. This additional mode between sleeping and shutdown, see definitions in chapter 5.1, has an energy consumption of almost zero (350 times lower compared to the sleeping mode). This is reached by lowering the pantograph, switching off the main switch and almost all equipment. Only some cooling devices, mainly for food products in dining cars, and surveillance systems continue to work. The train can be woken by remote control. It is assumed that this parking mode significantly reduces noise levels, which, however, has not yet been studied in detail. This particular operating mode is currently being tested in Switzerland by SBB and BLS.

Similar initiatives on reduction of energy consumption of parked trains have been launched in other countries. In addition, UIC is also in the process of initiating a project with its Sustainability Platform members to revise UIC Leaflet 345 [25] and create a new IRS 30345 and it is planned to integrate the outputs of this report on parked and stationary trains into IRS 30345.

Figure 22 shows two examples of a fresh-air intake of a passenger HVAC system. The standard intake (on the left) causes flow noise at the grid, whereas the acoustically optimised intake has a more favourable grid design and additional acoustic absorption materials. However, the acoustic gain and whether this solution is finally implemented on rolling stock is not known.

Figure 22: Fresh-air intake of a passenger HVAC (left: standard, right: acoustically optimised) [24]

A significant, however subjective, noise improvement for nearby residents was achieved by Deutsche Bahn by retro-fitting the air compressor exhaust valve with mufflers. This solution was applied to two types of regional EMU's. According to Deutsche Bahn the cost-benefit balance is very satisfying with costs per muffler between €1000 and €3500.

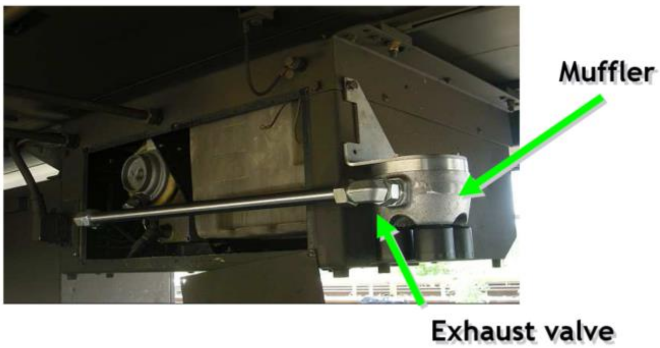


Figure 23: Air compressor exhaust valve with muffler, © provided by Deutsche Bahn.

Concerning parking at a terminus of a line, it could be interesting to look into the option to start the preparation for resting before the terminus is reached. This could be particularly interesting for hybrid vehicles, which could, for example, run the last mile in battery mode instead of the primary engine (diesel or electric with pantograph). This requires modifications to the vehicle's software and also operational procedures.

9.2. Noise mitigation measures taken by operators

In contrast to the previous chapter 9.2 describing measures to reduce noise from parked trains being applied to rolling stock, the present chapter demonstrates exemplary measures taken by railway operators.

The following examples from the Netherlands (the railway operator; NS) illustrate successful noise reduction measures for parked trains:

- For a regional train, the original HVAC design had a condenser fan which could only run at one speed. This caused many complaints from residents when a train was parked near their houses. By adding a lower fan speed via a software and hardware change, the noise was reduced by almost 9 dB.
- For the same regional train, the noise of the exhaust valve of the compressor on the roof caused many complaints. By adding a damper, the noise was reduced by almost 6 dB.
- For a double decker train, the HVAC was replaced by a heat pump during midlife overhaul. The disadvantage of a heat pump is the higher noise when heating the train. Therefore, the software was programmed in such a way that a parked train, may heated by electrical heating, thus not using the heat pump. This reduces the noise by more than 15 dB.

The following examples from Switzerland (operator SBB) illustrate a variety of measures, which are mainly aiming at reducing the activity time of technical components:

- For a regional train, a series of measures were implemented:
  - Half of the unit is switched off (main switch off) and 2 or 3 out of 4 transformer pumps are shut down.
  - The air compressor activity time is reduced by shutting down the bioreactor ventilation.
  - A higher temperature difference is allowed in the unoccupied driver's cab, leading to less runtime of the HVAC compressors and ventilation.
  - Noisy automated safety tests are no longer carried out in the early morning hours.
- For an older regional train, the switch-on hysteresis of the compressed air supply system was optimised. Furthermore, the compressed air supply system is electrically disconnected from the traction cooling system.
- One of SBB's major electrical locomotives was recently modernised: energy and noise optimisation were considered: the main compressor was replaced by two smaller units, such that one can be switched off during parking. Significant noise reduction is expected, but not yet analysed in detail.

These measures lead to a reduction of the critical distance for parking: in Switzerland, the criticality of the parking noise performance of different rolling stock is assessed in terms of a critical distance to respect a sound pressure limit at the receiver (immission limit) of 50 dB(A) during the night. Retrofitting of the three older types of rolling stock mentioned allowed this distance to be reduced by between 30% and 50%, reaching values of modern rolling stock [source: consultation by email].

Furthermore, participants of the UIC survey [7] listed the following measures concerning operational procedures to reduce noise from parked trains:

- Limited operation time of technical components.
- Reduction of the duration of noisy procedures during parking.
- Efficient and optimised temperature regulation in the unoccupied passenger saloon or driver's cab, meaning less operation of the HVAC system.
- Switching off diesel units during refuelling.

Correct implementation of these operational procedures for the different standstill regimes is a key element of ensuring that the most silent mode is set. This should be ensured by training of the drivers, but also by regular verification by team leaders and managers.

9.3. Noise mitigation measures taken by infrastructure managers

The current chapter provides some examples of measures taken by railway infrastructure managers to combat noise from trains at a standstill.

A first step towards a solution for residents might be the installation of a permanent noise measurement station. One example from a noise hotspot with a high level of complaints in Malakoff neighbourhood in Paris, France (see Figure 24), where BRUITPARIF[1] has installed a monitoring station. TGV trains being parked or stopped cause noise nuisances to residents, mainly due to noise from the engine cooling system [19] (see also chapter 8.1).

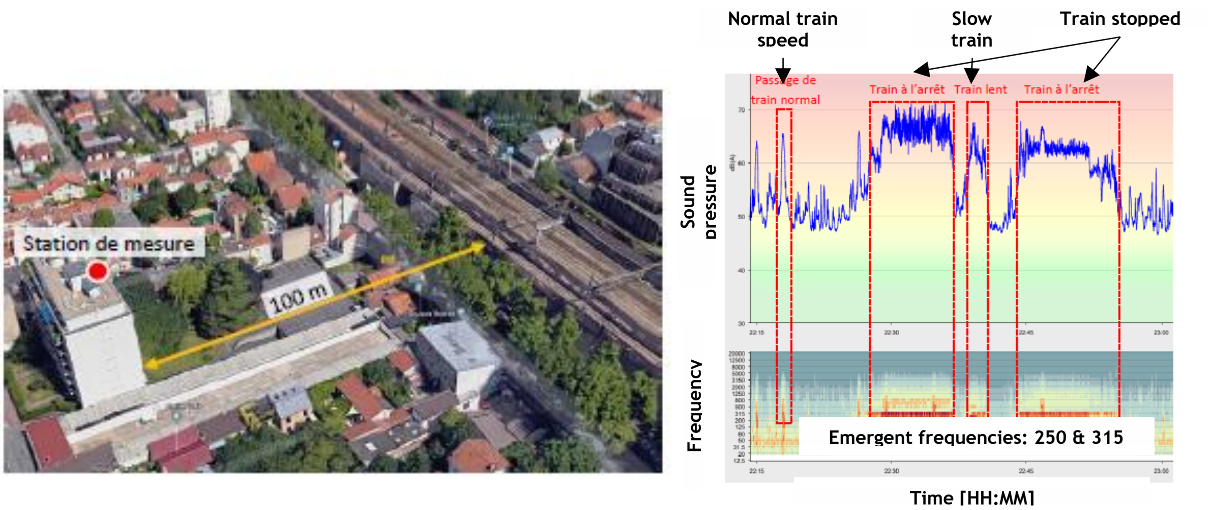


Figure 24: Noise measurement station in Malakoff quarter, Paris, France, © BRUITPARIF [19]

ProRail (Netherlands) is responsible for complying with noise limits from the environmental laws and for the capacity allocation process. M+P developed a "Dynamic Noise Model" (DNM) to evaluate noise levels of different activities in depots and shunting yards [26]. Noise sources are separated in stationary processes which take place on fixed locations and moving the train between these locations. The train operation mode for parked trains is distinguished in active (nearly all equipment is turned on), inactive (some equipment is turned on: power consumption and noise production are

[1] https://www.bruitparif.fr/observatoire-de-l-environnement-sonore-le-long-du-reseau-sncf-francilien/

low) and down (no equipment is turned on). The tool can be used to easily identify the processes causing high noise levels, optimise depot and shunting yard activities, calculate noise production per operator and assess the cost efficiency of noise measures. The main drawback of the tool is that sound attenuation in the propagation path between the source and receiver is constant.

The UIC survey [7] revealed that infrastructure managers implement the following noise mitigation measures:

- Noise barriers are widely used with the advantage of being a visible measure. The major drawback is, however, that their efficiency depends on their height, which might not be sufficient to reduce noise from roof-mounted components. However, it is worth mentioning that roof-mounted components generally need less cooling than underfloor components and by consequence emit less noise.
- Special parking orders: loud trains are parked far from residential buildings and silent or shut-down trains are used as noise barriers.

Deutsche Bahn (Germany) identified that some noise complaints concerning parked trains are related to erroneous settings caused by the train driver. In some parking areas this was controlled manually by a specially trained staff/depot movement controller and noise complaints were reduced. However, this improvement was not measured quantitatively. Currently, a surveillance programme based on an automated acoustic measurement station has been launched on a test site.

9.4. Land use planning

Noise from railways should always be part of land use planning. Noise from parked trains is however often neglected in these considerations since the general public, city planners, architects or public officers of local authorities are not aware of possible acoustic nuisances in this train operating mode or in a particular area close to a railway installation [7]. This may lead to complaints from residents as exemplarily described in chapter 8.1.

UIC with the members of the NV sector suggests that railway noise be considered in a broader framework with regards to land use planning: this includes information from the above-mentioned stakeholders on possible issues and nuisances, but also feasible solutions.

Concerning solutions, the following aspects should be considered by local and national authorities, not only for residential areas where new real estate will be built, but also for existing residential areas, close to the shunting yard and depots:

- Gather baseline information on land transport noise,
- Assessment of noise by carrying out environmental noise studies in order to identify critical zones and map hotspots,
- Structural restrictions: obligations to install sound insulations in buildings within already existing railway yards or depots,
- Define setback/buffer zone distances from shunting yards, railway depots and stations based on land use types and traffic density,
- Use of natural-based solutions as sound buffers such as green slopes or hedges (see B.1. Case Study 1 -Stationary Noise from Trains [5]),

- Urban design: minimise noise agglomerations and consider noise caused by shunting and parked trains,
- Develop monitoring programmes using baseline information and exchange information with railway authorities (see an example from Germany on Chapter 8.1),
- Cooperation between the project owner, residents, authorities, and railway companies already during the design/planning phase.

10. Engaging the community

Railway operators, infrastructure managers and manufacturers, as well as authorities and citizens, are all in agreement that noise from trains at a standstill, in particular noise from parked trains, needs a combined effort to reduce acoustic nuisances and improve the quality of life around railways. Nevertheless, the topic requires a collective effort to accelerate processes.

10.1. Railway stakeholders

UIC's Noise and Vibration Sector considers that further discussion is required with the rolling stock manufacturers. A continuation of the exchange with UNIFE with its Noise Group during this study is desirable in order to clarify outstanding points, such as a common understanding of train operating modes and measurement procedures.

10.2. Authoritities

Another aspect concerns informing local or regional authorities (see chapter 9.4 on land use planning) about noise from parked trains. In some countries, regional authorities are the owner of the rolling stock, in particular for regional services, and are therefore responsible for the acquisition of the train sets. According to the consultation during this study, UIC members suggested that noise from trains at a standstill should be carefully considered in the technical specifications of the tenders (see also chapter 9.1). They also emphasised the significance of information sharing with the railway operators and infrastructure managers in this regard.

10.3. Future developments

Concerning future topics related to noise from trains at a standstill, participants of the UIC survey [7] mentioned the following items:

- Reduction or replacement of horn tests,
- Clear regulations and assessment methods,
- Increasing traffic and residential density,
- New and retrofitted trains need to be quieter,
- More active and effectively manageable electric systems (e.g., individually operable and programmable systems, smart energy-saving solutions),
- Less noise tolerance among residents,
- Increasing number of initiatives for building over and close to depots and stations

Based on the information exchanges with UNIFE, noise experts from rolling stock manufacturers also underline the fact that a common understanding of parking noise shall be ensured in particular with regards to operating conditions [8].

11. Improving noise indicators

Reducing noise from trains at a standstill can be achieved based on relevant noise indicators. These are obtained by defining an assessment procedure, including a measurement or calculation procedure, an operating condition, and the choice of the measured quantity. Limit values can be defined on the basis of such an indicator and are the responsibility of the legislators.

Concerning indicators for noise emission:

- In order to further reduce noise from stationary trains, stricter limit values in regulations such as the TSI NOI are required, since the measured quantity and procedures are already well defined in standards such as ISO 3095.
- For noise from parked trains, currently no limit value is defined in TSI NOI. Progress can be achieved by homogenising the definition of noise indicators. This is currently in progress as one can see from the activity in the EN ISO working group, see chapter 6.6 and the work done in the current study, as well as the discussions between international railway players such as UIC and UNIFE. Collecting the values of such a homogenised indicator is necessary in order to build up a database, which allows reasonable and feasible limit values to be defined for a future revision of TSI NOI. This input will help CER's work on the TSI-NOI revision.

Nevertheless, limit values generally only concern new rolling stock, meaning that it will take a long time before noticeable changes reach affected residents. Therefore, from a resident's point of view, noise indicators should also aim to force improvements on existing rolling stock and infrastructure. This is probably only feasible at a national level due to differences such as noise sensitivity, costs of retro-fitting, financing, technical and administrative requirements in each country. Adding maximum sound limits at any time, as practiced in some countries, to the existing long-term values could be an interesting way to achieve this, see chapter 6.8.

11.1. Suggestions for tsi values

Noise limit values for parked trains are difficult to define with the currently available data, see the examples given in Chapter 7. The data are not comparable, mainly due to different assessment / measurement procedures and train operating modes. The new Annex G of the current revision of the EN ISO 3095 standard [12] overcomes these drawbacks and will make it possible in the future to establish a database for noise from parked trains. In order to identify limit values that might possibly be discussed in the TSI NOI revision for 2025–2027, it is crucial to promote specific measurement campaigns with a defined plan and strategy in the near future.

Concerning the indicator used to define limit values, UNIFE's noise group suggests that single vehicle indicators in accordance with the new Annex G of the revised ISO 3095 standard [8] should be applied. The operators suggest one indicator be used for each noise source, measured separately, instead of one single vehicle indicator. A discussion between relevant noise groups of the sector (CER, UNIFE and UIC) is foreseen in order to better comprehend and examine this argument.

12. Conclusions and next steps

The last UIC report on Railway Noise in Europe [27] showed “that railway traffic is a transport sector leader on safety, air quality and CO_2 emissions, as well as having a low impact on health and the environment in general”. The railway sector is aware that noise is one of the major negative impacts on the environment and may cause a significant impact on health. Therefore, the sector, and in particular UIC, is working to further decrease noise from railways and to make them quieter in the future.

Noise from trains at a standstill, in particular from parked trains, has been identified by UIC’s NV Sector as one of the major noise topics to deal with, especially since no limit values, e.g., in the TSI NOI regulation, have been defined since UIC’s last report on the topic in 2014 [3].

The present study aimed to critically analyse the current state of noise from trains at a standstill.

During the present study it became clear that the entire railway sector, including infrastructure managers, railway operators, rolling stock manufacturers and policy makers agree on the fact that noise from trains at a standstill has to be controlled and reduced in the future. In order to achieve this, a common understanding of the definition of noise from trains at a standstill, in particular from parked trains, is necessary. Topics such as the definition of train operating modes, exterior climate conditions and assessment procedures are still under discussion in the sector. Opinions between the stakeholders are still diverging due to different objectives: for example, infrastructure managers have to respect noise limits at reception points such as residential buildings (*immission*) and rolling stock suppliers need to secure and simplify homologation procedures.

Concerning assessment and measurement procedures, the current revision of the ISO 3095 includes parking noise. Rolling stock manufacturers seem to prefer the suggested procedure and are reluctant to move towards supplementary specifications such as EuroSpec or VDV, apparently due to lack of clarity. Infrastructure managers and railway operators generally consider the suggested revision of ISO 3095 as a step in the right direction; they insist however on specifications such as EuroSpec or VDV which allow more detailed acoustic data to be obtained per technical component. The latter is required in particular for environmental noise studies (*immission*).

In order to define limit values for noise from trains at a standstill and in particular from parked trains, a solid acoustic database is required. The acoustic data analysed in this study clearly showed that the available data are not comparable in a quantitative way, due to differences in train operating modes and measurement procedures. Nevertheless, the analysis showed that variability of noise levels exists depending on the component type, train class and operating mode. A more advanced analysis is recommended to prepare a dedicated measurement campaign in the future. It is recommended the focus be on the most common rolling stock within the European market and that a common approach be agreed between the different stakeholders.

The mentioned measurement campaign with a defined strategy is a compulsory step towards noise limit values for parked trains and should be launched within the near future.

Noise mitigation measures were also analysed in this study. Generally, mitigation should start with the loudest and dominant source. A series of technical solutions exists to reduce noise from trains at a standstill. Technical modifications, however, require detailed techno-economic studies, consideration of side effects (impact on safety, for example) and are strongly dependent on the particular case. Nevertheless, a series of relatively simple measures to reduce noise from trains at a standstill, in particular parked trains exist:

The correct application of the required standstill mode by the train driver should be checked and encouraged by team leaders or recalled during training.

Furthermore, it seems that some stakeholders (e.g., local authorities with regard to land use planning or regional authorities defining tenders for new rolling stock) are not aware of the potential noise issues from trains at a standstill. Again, rising awareness and training can be an efficient way to prevent issues and to ensure residents’ quality of life.

References

[1] Official Journal of the European Union, “Commission Regulation (EU) No 1304/2014 on the technical specification for interoperability relating to susbsystem 'rolling stock - noise' amending Decision 2008/232/EC and repealing Decision 2011/229/EU,” November 2014. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R1304. [Accessed August 2022].

[2] Official Journal of the European Union, “Commision implementing regulation (EU) 2019/774 amending Regulation (EU) no 1304/2014 as regards application of the technical specification for interoperability relating to the subsystem 'rolling stock - noise' to the existing freight wagons,” May 2019. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019R0774. [Accessed August 2022].

[3] International Union of Railways (UIC), Müller-BBM GmbH, “Managing Noise from Parked Trains,” November 2014. [Online]. Available: https://uic.org/IMG/pdf/m111955_04_ber_3e_couv.pdf. [Accessed August 2022].

[4] European Commission, “EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil',” May 2021. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0400&qid=1623311742827. [Accessed 23 June 2022].

[5] International Union of Railways (UIC), “Nuisance and health impact of railway noise,” Noise and Vibration Sector, 2022.

[6] Verband öffentlicher Verkehr (VöV/UTP), “D RTE 48610: Steuerung energieeffiziente Parkstellung Rollmaterial,” October 2021. [Online]. Available: https://www.voev.ch/de/Technik/RTE-Webshop/Start/Detaillierte-Produktedaten?productId=2103. [Accessed August 2022].

[7] UIC Noise and Vibration Sector (NOVITÀ project), “Management of Noise from Parked & Stationary Trains - Infrastructure Managers & Operators,” VibraTec, 2021. [Online]. Available: https://uic.org/projects/article/novita#UIC-Noise-and-Vibration-Sector-scoping-studies. [Accessed August 2022].

[8] International Union of Railways (UIC) - Management of Noise from Parked and Stationary Trains - Survey for Rolling Stock Manufacturers, “Consolidated responses from the UNIFE Noise Expert Group - consultation,” 2022. [Online]. Available: https://uic.org/events/parked-and-stationary-trains#Survey-for-Rolling-Stock-Manufacturers.

[9] Bundesamt für Umwelt BAFU, EMPA, “Beurteilung und Begrenzung des Lärms von abgestellten Zügen,” January 2012. [Online]. Available: Beurteilung und Begrenzung des Lärms von abgestellten Zügen. [Accessed 2022].

10] European Union Agency for Railways (ERA), “Guide for the application of the NOI TSI,” 2019. [Online]. Available: https://www.era.europa.eu/sites/default/files/activities/docs/application_guide_noi_tsi_en.pdf. [Accessed August 2022].

[11] ISO/TC 43/SC 1 Noise, “ISO 3095:2013 Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles,” August 2013. [Online]. Available: https://www.iso.org/standard/55726.html. [Accessed August 2022].

[12] *pr EN ISO 3095 Annex G Parking Noise* (Draft 2021-06-28), 2021.

[13] Verband Deutscher Verkehrsunternehmen e. V., “Geräusche von Eisenbahnfahrzeugen in der Fahrzeugabstellung einschl. Vorbereitungs- und Abschlussdienst,” November 2017. [Online]. Available: https://www.beka-verlag.info/VDV-Mitteilungen/Fahrzeuge/Schienenfahrzeuge-OePNV/VDV-Mitteilung-1541-Geraeusche-von-Eisenbahnfahrzeugen-in-der-Fahrzeugabstellung-PDF-Datei::431.html. [Accessed August 2022].

[14] EuroSpec, "Specification Parking Noise," June 2019. [Online]. Available: https://eurospec.eu/wp-content/uploads/2019/06/EuroSpec-Parking-Noise-v1.0.pdf. [Accessed August 2022].

[15] BAFU Schweiz, EMPA, "Determination of industry and commercial noise: Zusammenfassung des Empaberichtes und Excel zur Berechnung des Lärms von abgestellten Zügen basierend auf den Untersuchungen der Empa," October 2021. [Online]. Available: https://www.bafu.admin.ch/dam/bafu/de/dokumente/laerm/fachinfo-daten/berechnungstool-agbestellte-zuege.zip.download.zip/ZusammenfassungBericht_und_Berechnungstool.zip. [Accessed August 2022].

[16] New South Wales Government - Transport Asset Standard Authority, "RSU 100 Series – Minimum Operating Standards for Rolling Stock – General Interface Requirements," December 2018. [Online]. Available: https://www.transport.nsw.gov.au/industry/asset-standards-authority/find-a-standard/rsu-100-series-minimum-operating-standards-for. [Accessed August 2022].

[17] Deutsche Bahn (DB Netz AG), "Handlungsempfehlung zur Anwendung der TA Lärm bei Eisenbahnbetriebsanlagen," 2021.

[18] B. Derveaux, "Le bruit des TGV exaspère les riverains," Le Parisien, 27 August 2016. [Online]. Available: https://www.leparisien.fr/hauts-de-seine-92/le-bruit-des-tgv-exaspere-les-riverains-27-08-2016-6071885.php. [Accessed 12 October 2021].

[19] BRUITPARIF, "Mesure du bruit à Vanves-Malakoff (Approche Technicentre Atlantique)," Paris, 2021.

[20] France 3 Centra Val de Loire, ""C'est l'enfer" : près de Chartres, des riverains vent debout contre une station de maintenance de la SNCF," 25 March 2021. [Online]. Available: https://france3-regions.francetvinfo.fr/centre-val-de-loire/eure-et-loir/chartres/c-est-l-enfer-pres-de-chartres-des-riverains-vent-debout-contre-une-station-de-maintenance-de-la-sncf-2015842.html. [Accessed 12 October 2021].

[21] N. Kampe, "Düsseldorf-Eller: Eisenbahn-Bundesamt will Lösungen suchen," Rheinische Post Online, 16 August 2019. [Online]. Available: https://rp-online.de/nrw/staedte/duesseldorf/stadtteile/eller/duesseldorf-eller-eisenbahn-bundesamt-will-loesungen-suchen_aid-45029805. [Accessed 13 October 2021].

[22] I. Hilberth, "Aus dem Schnalzen ist ein Brummen geworden," Süddeutsche Zeitung, 04 September 2019. [Online]. Available: https://www.sueddeutsche.de/muenchen/landkreismuenchen/abgestellte-zuege-laerm-oberhaching-1.4588248. [Accessed 14 June 2022].

[23] Omroep West, "Omwonenden worden horendol van herrie locomotieven bij station Den Haag HS," 07 August 2019. [Online]. Available: https://www.omroepwest.nl/nieuws/3874993/omwonenden-worden-horendol-van-herrie-locomotieven-bij-station-den-haag-hs. [Accessed 14 June 2022].

[24] S. Liebing and M. Hecht, "Studie zur Lärmminderung des Abstellgeräuschs am ET2.442," TU Berlin, Berlin, 2015.

[25] International Union of Railways (UIC), "Eco Stabling - Parked trains energy management best practices," June 2022. [Online]. Available: https://uic.org/events/eco-stabling. [Accessed 05 07 2022].

[26] S. N. Hoogzaad and M. S. Roovers, "Optimizing Capacity of Railroad Yards within Noise Limits Using a Dynamic Noise Model," *Noise and Vibration Mitigation for Rail Transportation Systems - Proceedings of the 11th International Workshop on Railway Noise*, pp. 353-360, 2013.

[27] International Union of Railways (UIC), "Railway Noise in Europe - State of the art report," Paris, 2021.

Glossary

Terms	Definition
Emission	Corresponds to the emitted noise of an acoustic source
Immission	Term used in some countries / languages to describe the effect of one or several noise sources at a receiver location in the context of environmental noise considerations.
Idling	Used as a synonym for a stationary train.
Parked train	A parked train is one that is taken out of commercial service for a longer duration at one place. No passengers are on board, however the driver, guard or service staff might be present. Parking can be split up into 3 phases. “Stabling” can be used as a synonym.
Preparation for resting	A parked train mode. Technical components will leave the full operation mode during this phase and the train is prepared for resting.
Preparation for service	A parked train mode. Re-starting up of technical components of the train including engine, traction systems, HVAC, ventilation systems as well as pre-heating or pre-cooling of the driver and passenger areas.
Resting	A parked train mode. Activity of technical components is either temporarily, partially or totally turned down to save energy. Three different resting modes can be distinguished: standby (preconditioning to achieve fast operational availability), sleeping (energy-saving mode), shutdown (entire and complete system shut down)
Stabling	Used as a synonym for a parked train.
Standstill train	A train that is not moving. Its speed is zero. It can be either stationary or parked.
Stationary train	Fully operational train in commercial service, which is temporarily stopped (e.g. waiting for a signal, waiting to enter or leave a depot, in stations). Generally, the train is ready to accelerate. “Idling” can be used as a synonym.

Abbrevations

Abbrevation	Definition
BLS	Bern-Lötschberg-Simplon, a Swiss railway company
BRUITPARIF	A non-profit environmental organization responsible for monitoring the environmental noise in the Paris agglomeration
CEN	Comité Européen de Normalisation – European Committee for Standardization
CER	Community of European Railway and Infrastructure Companies
DB	Deutsche Bahn, a German federal railway company
DMU	Diesel Multiple Unit
E-loco	Electrical locomotive
EMU	Electric Multiple Unit
EuroSpec	European Specification for Railway Vehicles, a consortium of six European train operating companies (NS, DB, SNCF, ÖBB, SBB, RDG)
HVAC	Heating, ventilation and air-conditioning system
NS	Nederlandse Spoorwegen, Railway operator in the Netherlands
NSW	New South Wales, Australia
ÖBB	Österreichische Bundesbahnen, the Austrian federal railways
ProRail	Dutch federal railway infrastructure manager
RDG	Railway Delivery Group – British rail industry membership body
SBB	Schweizerische Bundesbahnen, Swiss federal railway company
SNCF	French federal railway company
SOB	Schweizerische Südostbahn, Swiss South Eastern Railways
TGV	French high-speed train
TSI NOI	Technicial Specification for Interoperability – Noise
UNIFE	The European Rail Supply Industry Association
VDV	An association of German Transport Companies

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