Rail Dampers, Acoustic Rail Grinding, Low Height Noise Barriers

A report on the state of the art

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1. Summary

There are many noise mitigation options open to railways. Some of them - such as noise barriers - have a known effect and are used widely, others such rail dampers, acoustic rail grinding or low height noise barriers are still controversial for various reasons. Since each railway has limited opportunities to extensively test these controversial measures, the Network Noise of UIC decided to collect results and measurement conditions of these three noise abatement measures. This report first describes some elementals of noise control as well as quantities that are important for understanding the arguments made. It then describes the three noise mitigation methods in more detail, explains why they are controversial and finally lists and comments on the experience made to date.

The experience in other countries was obtained by asking members of the UIC Network Noise as well as representatives from other European countries. The request for information was sent in mid 2011. In addition this report was sent to Network Noise members in mid 2012 for comments and for additional results not available in 2011.A limited number of results where obtained from other sources.

The main conclusions of the report are:

Rail dampers:

- There is a large variability in the results ranging from small increases in noise to a maximum noise reduction of usually not more than 3 dB.
- The effects of dampers are influenced by many parameters such as construction (rail pad stiffness) or traffic. However for many of the results these parameters were not measured. Therefore it is difficult to compare the results or to use the results from one situation in order to predict the effects in another one.
- Network wide cost-benefit analyses have not been undertaken to date. The ongoing Swiss project is the first to attempt this.
- The STARDAMP project and the ongoing Swiss trials are the first systematic approaches to the problem measuring all relevant parameters. The results of these projects still outstanding and will be included in further editions of this report.

Rail grinding:

Only two countries – Germany and The Netherlands – have implemented acoustic rail grinding procedures. In Germany the procedure allows a legal noise reduction of 3 dB, regardless if this is achieved in practice or not while in The Netherlands specific noise reduction aims are defined.

Lacking are network wide cost benefit analyses. It is suggested that these are undertaken, best in a cooperative approach by the railways.

Low height noise barriers:

There is not much information available on low height noise barriers to date and the trials are mostly not precise enough to undertake a final conclusion on the issue. The basic arguments are still the same: From an acoustical point of view low height barriers are comparable r to normal barriers and they have the advantage of fitting into the landscape. On the other hand, there is not yet enough experience to satisfactorily address maintenance and security questions. Some countries (e.g. Norway) do not report problems, others (e.g. Switzerland) are not pursuing the issue because of these con

2. Introduction and aim of study

There are many noise mitigation options open to railways. Some of them - such as noise barriers - have a known effect and are used widely, others such rail dampers, acoustic rail grinding or low height noise barriers are still controversial for various reasons. Since each railway has limited opportunities to extensively test these controversial measures, the Network Noise of UIC decided to collect results and measurement conditions for these three noise abatement measures. This will enable UIC members to profit from the experience of the other railways.

This report first describes some basic elements of noise control as well as quantities that are important for understanding the arguments made for the three noise abatement measures. It then describes the three noise mitigation methods in more detail, explains why they are controversial and finally lists and comments on the experience made to date.

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Since not all railways responded, it is likely that this report is incomplete. New editions of this report can, however, easily be made if new information becomes available.

This report is intended as a state of the art and does not make recommendations concerning how the measures could be improved in order to gain more acceptance with infrastructure managers.

3. Overview of railway noise

Railways are noisy and often in close proximity to people, therefore railways must deal with this problem. Noise mitigation can be undertaken either at the source or in the propagation path.

The second part, noise propagation, is common to all types of sound propagation and is not specific to railway noise. Sound propagation has been well described by many models in which the noise created at the source travels through the air in waves to the reception point. Noise reduction along the propagation path is usually done with noise barriers, which absorb and deviate sound waves thus reducing the energy carried by sound waves. Low height barriers in close proximity to the tracks are one issue treated in this report.

On the other hand, noise creation is specific for railway noise and not all mechanisms are understood in detail yet. Because there are different noise sources, noise creation is usually divided into different part, which, by decreasing importance, are:

1. Rolling noise
2. Aerodynamic noise

3. Other noise sources such as engine noise, pantograph noise, etc.

The total noise creation is a sum of all these contributions. Rolling noise itself is a sum of track, wheel and sleeper noise.

At this point a trivial but important remark must be made; since noise is normally given in terms of dB (or dB(A)) we must keep in mind that when we speak about sum we deal with logarithmic sums (two noise levels of L1 and L2 are summed give $L1 + L2 = 10\log_{10}\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}}\right)$). As a consequence the main noise source usually determines the final noise creation level and thus we can usually neglect sources with lower noise levels. In this report we will see that this consideration will be used to comment and to understand many experimental results.

Noise creation reduction is obtained reducing the emission from those sources that contribute to the total emission. This is usually done by decreasing rolling noise sources. Rail dampers and acoustic rail grinding are the two measures of this category that will be discussed in this report. In order to better understand these two measures, rolling noise is described in more detail in the next chapter.

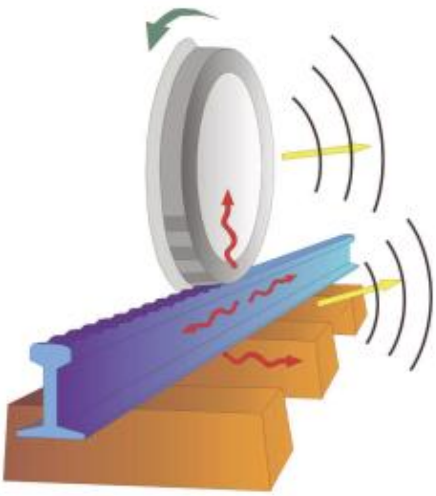
4. Mitigation measures on rolling noise

4.1. Introduction to rolling noise

Before discussing rail dampers and rail grinding it is useful to better understand rolling noise. Rolling noise is quite complex and without a suited theoretical and scientific approach is difficult to understand all of the mechanism involved, including the mitigation measures. However, if we ignore the scientific approach, this leads to controversial results, as will be seen later in this report.

On the theoretical side much work to understand rolling noise has been made and different models have been studied. In the 1990s, based on these models, a software called TWINS (Track Wheel Interaction Noise Software) was developed to calculate different rolling noise situations. Unfortunately these models describe a simplified view of the problem and they are not enough accurate for practical purposes in all situations. The development of those theories and software is not finished yet and much research is still being undertaken. The final aim is that the models can accurately predict the effects of noise mitigation methods.

As previously mentioned rolling noise is a sum of rail, wheel and sleeper noise. The mechanism of rolling noise used in the model (see **Figure 1** and 2) and based on TWINS can be described in a simplified way as follows.



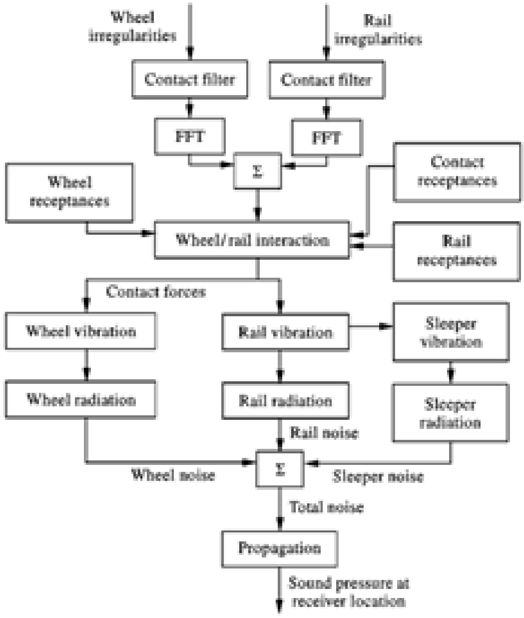


Figure 1 (left): Noise creation mechanism.
Figure 2: Diagram of the noise creation in TWINS model.

The model begins by considering that the surface of the rail head and of the wheel is not smooth but irregular. By the motion of the wheel along the rail these irregularities cause the wheel and the rail to vibrate, resulting in noise. These imperfections are of various types: Periodic irregularity is usually called corrugation and broadband irregularity is called roughness. For the purposes of this report, we will consider roughness and not corrugation. The latter is a question of normal maintenance procedures and does not usually concern noise mitigation.

In the model the roughness of the rail and the wheel are combined to form total roughness, which is used as the force that excites the wheel and the rail. The response of wheel and rail to the exciting forces is then predicted by the oscillating characteristic of the rail, the wheel and the interaction between them. The response of the single components will then determine the acoustic radiation of the component. An important point arising from those models is that the noise emitted at a given frequency is proportional to the total roughness at this frequency.

The following two parameters of the rolling noise model are of fundamental importance:

Track decay rate

The track decay rate (TDR) is a quantity which describes the oscillating characteristics of the rail. The TDR is distinguished for vertical and horizontal oscillation modes. In more precise terms the TDR describes the rate of attenuation of vibration along the rail, that is if R is the factor of reduction of the amplitude of the wave over a meter then the TDR is given by $-20\log_{10} R$. The TDR is normally given in dB/m and it depends on the frequency of the oscillation. Measuring the TDR on the track has become a common procedure. The measurement method consist in the excitation of the rail with a hammer and in the measurement of the response functions between impact force and acceleration at different distances. A high TDR implies that the vibration caused by the excitation on a point of the rail is damped in a short distance, a low TDR imply that the rail will still oscillate at greater distances from the point of excitement. It is clear that to get low noise emissions a high track decay rate at every relevant frequency is needed.

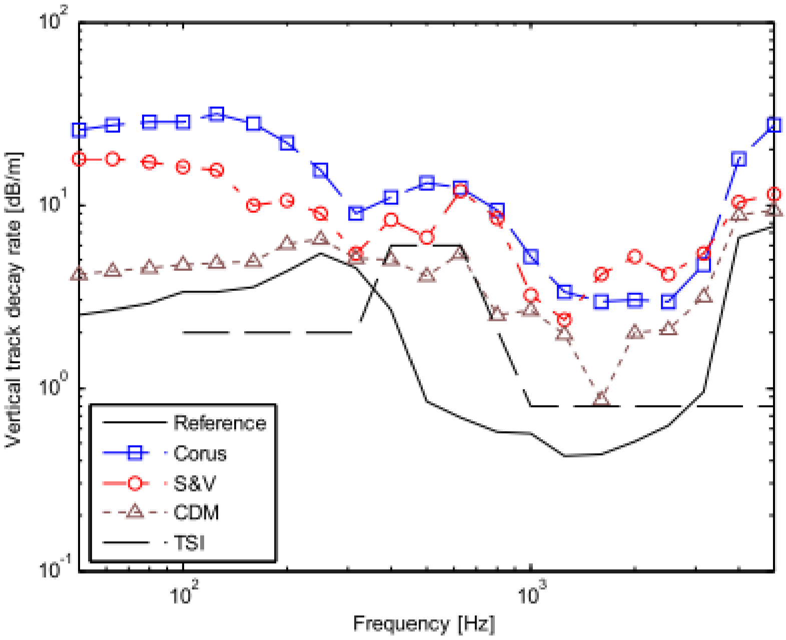


Figure 3: Example of TDR spectrum of track with dampers (figure from Qcity report[1])

At about 10 dB/m the reduction of the vibration is so high that the emitted noise can be neglected and thus increases of TDRs above 10 dB/m are irrelevant. The TDR depends on construction parameters and ground characteristics, which explains the large variations observed along the track. The high TDR at low frequencies (<400 Hz lateral, <700 Hz for vertical) occurs through the coupling of rail with sleeper and ground. One well known relevant parameter is the stiffness of the rail pad (rubber pad between rail and sleeper). A stiff (800 KN/mm) pad couples the rail tightly with the sleeper, allowing energy to flow from the rail to the sleeper. In this case the rail vibration will decrease resulting in a high TDR. With soft (e.g. 300 KN/mm) pads the coupling between sleeper and rail is weak and thus the TDR will be low. Much work has been done to relate TDR with ground and other construction parameters but until now the results are insufficient to make significant predictions.

Rail dampers are designed to damp vibrations in the rail, which corresponds to an increase of the TDR. Since increases above a TDR of 10 dB/m do not affect noise the absorber must be constructed in such as way, that those frequencies are damped, where the TDR is below this value.

Rail roughness

[1] Quiet City Transport, Performance report of applied measures – Malmö, Part 1, 2008

As mentioned previously the rail head is not smooth but rather possesses irregularities. Periodical irregularities are called corrugation and are normally well visible. They have wavelengths of about 20 mm to 100 mm and amplitudes of about 1/10 mm. Corrugation extends to 1 m wavelengths but, as we shall see, only wavelengths below 20 cm are acoustically relevant, even though the increase in forces due the corrugation represents a problem for the whole railway system (not only noise) and mitigations measure (grinding) against corrugation is implemented in normal maintenance procedures. Therefore rail grinding against corrugation is not part of this report.

Even if the rail head seems smooth and no corrugation is visible there are imperfections called roughness. Rail roughness exhibits a broad band characteristic (it is not possible to distinguish a single wavelength) and typical amplitudes are in the 1-100 micron range. Rail roughness is usually expressed in terms of a roughness spectrum (amplitude versus wavelength) where the amplitude is given in decibel units. This means that, if the amplitude at a particular wavelength is A then the roughness is given by $20\log_{10}(A/A_0)$ where A_0 is the reference amplitude of a micron (10^{-3} mm). For example a roughness of 0 dB corresponds to amplitude of 10^{-3} mm, a roughness of 10 dB to $3.2\text{x}10^{-3}$ mm and a roughness of 20 dB to 10^{-2} mm.

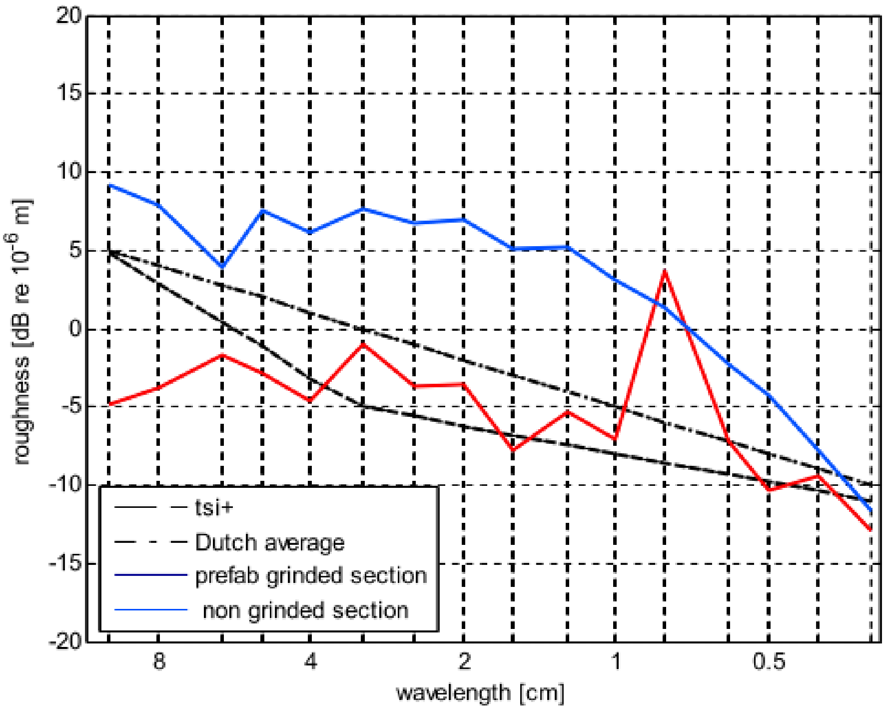


Figure 4: Example of roughness spectrum (Figure from M+P Report[2]).

The frequency of the exciting force created by a (rough) wheel rolling on a rough rail depends on the moving velocity and on the roughness wavelengths and in related to it by the equation $f = v/(3.6\, wavelength)$ (velocity in km/h). It follows that the wavelengths of the roughness spectrum of

[2] Measurement report, *Rail roughness of railway track with prefab grinding, M+P, 2008* commissioned by ProRail

particular relevance to rolling noise are between 5 mm and 20 mm. To illustrate this relationship roughness wavelengths of 2 mm and 20 mm will generate a vibration excitation at 1400 Hz and 140 Hz respectively at 100 km/h.

After these considerations it is clear that the monitoring and the mitigations measures against acoustical roughness must be different from those against corrugation. This will be discussed further in the chapter on acoustic rail grinding.

4.2. Rail dampers

4.2.1. What are rail dampers?

Rail dampers are elements that are fixed on the side (normally on both sides) of the rail and some types also have a part under the rail. Discrete rail dampers are placed on the rail at periodic distance, usually between every sleeper. Continuous rail damper are placed along the whole length of the rail, a configuration that is not often used.

The principle of rail dampers is the following: The aim is to reduce the oscillation of the vibrating rail by coupling it to a mass (steel elements in the damper) by a damped spring (rubber between the rail and the steel parts of the damper). The energy of the vibrating rail will flow into the damper (the mass of the damper will vibrate) and in turn this energy will be dissipated by the damping characteristics of the rubber. The effect of the damper on the rail is similar to increasing the damping factor of the rail which as a consequence increases the TDR.

The oscillating frequency where the flow of energy from the rail to the damper is possible depends on the stiffness and on the damping coefficients of the rubber. Changing the coefficients (rubber type) and the design it is then possible to shift or spread the working frequencies of the damper and optimize the dissipation of the transferred energy. Therefore, different designs of dampers have effects at different frequencies.

In reality the design of such a damper is quite a bit more complex than it looks. Problems arises from the fact that rubber is a material where stiffness and damping characteristics depend strongly on load, frequencies and on temperature (recent experience shows that temperature probably has a much larger effect than originally thought). To take these effects into account it is expected that there is still potential for development in the rail damper market.

4.2.1.1. Why are rail dampers controversial?

The problem of rail dampers consists in the quantification of its efficiency. Different trials have shown strong variation in the effects, usually ranging from 0 dB to 3 dB with rare maxima of 7 dB. The effects are dependent on traffic and construction parameters. However, the influence especially of construction has not been quantified satisfactorily. Here are some of the critical points:

- **Large variation in effectiveness**: As shown in the experience (see further down) pass-by noise measurements of the effect of rail dampers varies greatly. This can in part be explained by the influence of different parameters (e.g. construction, traffic) on the effectiveness of dampers. For example if wheel noise is dominant, low effects of dampers are expected. Difficulties arise in particular because often not all parameters are known (for example wheels in the same train can have a different roughness) or the apparently same track may have different TDR over a short distance, because the ground changes. Comparisons of even apparently similar situations thus become difficult. Even in those parameters known to influence effectiveness (temperature, velocity) their specific influence is not. Currently also unknown are the effects of dampers on rail roughness growth – giving yet another unknown when determining effectiveness. Reasons for the difficulty in effectiveness assessment are:

    - **Correct assessment difficult and expensive:** The influence of many different parameters show that a correct design of the trials is of paramount importance. Usually, however, this is not done due to lack of finances or know-how and therefore only limited insights can be gained. For example reference measurement are not done at the same location (possible change in TDR), at different times (change in roughness and temperatures), or with different rolling stock (different wheel roughness). In general is the problem so complex that the correct testing procedures are expensive and long. It is usually helpful to not measure noise directly but rather to measure TDR and to infer noise from those measurements.

    - **Theoretical models also problematic**: Theoretical models try to answer this question too, in this case the parameters which should describe the situations are assumed and then the effect is calculated through the model. There are various problems: It is often unknown which parameters will have an influence in a specific situation. (e.g. pad stiffness, ground, roughness, TDR without,…). Also every model is a simplification of reality and some parameters such as temperature or the inhomogeneity of the ground are not taken into account.

    - **Unclear effects on infrastructure:** Dampers are a new element in infrastructure. The effects on maintenance, track diagnosis, roughness and corrugation have not been studied sufficiently. A further concern is the additional mass added to the rails.

Because of the controversy, many railways are working on the problem. Currently the main focus is to combine theoretical models with trials. The French-German STARDAMP project is one of the largest projects to date, followed perhaps by the systematic approach chosen in Switzerland where both acoustic and infrastructure concerns are addressed.

4.2.1.2. Manufacturers of rail dampers

There are several different manufacturers of rail dampers on the market, using different construction principles with slightly different functioning mechanisms. Currently the most commonly used dampers are the products by TATA (CORUS) and Schrey & Veith. Next in line are the dampers by Vossloh and

STRAIL. In the literature other dampers such CDM, Edilon and Tiflex are mentioned, however not much is known to date (most of the information is from The Netherlands and Sweden for CDM). Detailed information is given in a ProRail report[3] which describes different dampers and how they are constructed. Even though this document dates from 2006 and contains practically only the Dutch experience it gives a good overview of most of the dampers tested until that time. It must be noted that there are measures similar to dampers (e.g. Quiet stone, Calmmoon-Rail of SEKESUI) but whose method of functioning is more similar to a small noise barrier than to an actual damper. These products are therefore not considered in this report.
The most common rail dampers are the following:

Schey & Veith
Schey & Veith has developed various types of absorbers (MKI, MKII). These products are among the most tested and reviewed. The system consists of two to three active elements fixed to the rail through a baseplate: Two active parts are located each side of the rail and there are models with a third part which is underneath the railfoot. The construction of each element consists of a stack of alternating layers of steel pieces and elastomer. To broaden the frequency range efficiency the steel masses have different widths. The overall mass added to the rail is nearly 70%.

TATA Steel
TATA Steel's SilentTrack (the damper developed at CORUS) is the second well know product. The system is based on three mass in a vertically stacked arrangement coated with an elastomer. The function of the elastomer is twofold: to produce the stiffness and damping effect of the mass-spring system and protect the steel masses from corrosion. These are laterally clipped to the rails using elastic springs and glue. The overall added mass to the rail is nearly 30%.

Vossloh
The Vossloh damper system consists of composite element with a steel core. The damper is clipped to the rail with glue or with steel clamps.

STRAIL
STRAIL produces a damper called STRAILastic_A which is a product made of an elastomer compound. Based on its large mass, the absorber functions as a mass damper. Unlike other rail dampers STRAILastic_A does not contain steel. The damper is laterally clipped on the rail using clamps.

[3] *Practical experience with rail dampers*, ProRail Rail Noise Knowledge Centre,2006

Figure 5(left): Tata Steel
Figure 6: S&V

Figure 7(left): Vossloh
Figure 8: STRAIL

Photographs of the four main damper types. Pictures were taken during the car park tests in Hägendorf (see experience in Switzerland).

4.2.2. Experience with rail dampers

In the following section we have reviewed the most important experiences with rail dampers to date. First a country by country description is given, followed by a table summarizing the noise mitigation effects. References are given on the table at the end of this chapter.

4.2.2.1. Austria

In Austria trials with dampers on the line from Innsbruck-Bludenz were undertaken on a two way curve (Konzertkurve at Innsbruck) in 2008. The construction on this curve is wooden sleeper, UIC 60 rails and soft rail pads. Because this curve usually has high levels of roughness and corrugation, it was ground several times during the trials and the growth of roughness was studied. Three dampers were tested: Vossloh, Tata (Corus) and S&V, however in the reports the effects are given anonymously. Traffic on the “Konzertkurve” is mixed with both freight and passenger trains. Measurements of pass by noise level, TDR and roughness were undertaken.

Results:

- *Overall noise:* The decrease of the noise level for one damper were about 0.7 dB to 1.1 dB and 1.5 dB to 2.7 dB depending on the train type (BR4024and EC/IC). For the other dampers noise reduction was about -0.5 dB to 0.9 dB and 0.5 dB to 3.5 dB (BR4024and EC/IC). Because roughness changed during the trials, comparisons were difficult (for the third absorber it was not possible). Differences between train types are explained with the amount of noise radiating from the wheels.
- *Track Decay Rate:* The TDR was increased by the dampers.at frequencies from 800 Hz to 1.6 kHz. The increase was about 4 dB/m for the best dampers.
- *Roughness:* The curve displayed high roughness levels in both direction before the dampers were mounted (on the interior rail the levels were about 20 dB above the TSI values for at 5 cm to 15 cm wavelengths). Shortly before installing the dampers, the rails were ground, however the TSI levels could not be reached. After ten weeks the roughness of the interior rails in both directions increased dramatically and almost reached the levels before grinding. It is unclear how much of the effect is due to dampers. Probably the trial results were influenced more by roughness than by the dampers.

4.2.2.2. Czech Republic

In the Czech Republic, the Vossloh and Corus dampers have been used since 2008 and so far been installed on three track sections. A check noise measurement demonstrates that their efficiency decreases as a result of lower technical parameters of the operated cars (the top efficiency has been recorded with cars equipped with a disc brake, but the lowest efficiency with freight trains – however, this precaution should exercise a key function in this case). For the next period, it is expected to use the dampers in well-founded cases only where noise prevention walls cannot be installed (the same noise limits have to be guaranteed outdoors as well as indoors).

4.2.2.3. Germany

In Germany five different dampers were tested in 29 different locations for a total of 92 km in construction situations with sleepers and ballast. Total noise reduction was measured for trains with speeds between 50 km/h and 200 km/h. The results are summarized in the following table, a positive value is a noise reduction. It has to be noted that only the reduction in the frequencies between 500 Hz and 2.000 Hz were used to calculate the total noise reduction.

Table 1: Effect of Dampers for different train types

Train Type	**Damper 1**	**Damper 2**	**Damper 3**	**Damper 4**	**Damper 5**
ICE	2	1	2	NA	NA
IC	1	1	2	1	-1
NV (regional trains)	1	2	2	1	0
ET_S	3	NA	1	1	1

GZ (freight train)	1	2	3	2	NA
Average	2	2	2	1	0

Different dampers have different effects; the average noise reduction for the three damper types is 2 dB. The required noise reduction of 3 dB was not achieved.

Costs: The calculated costs summarized in the following table are an average of the building costs obtained from the 92 km of mounted dampers.

Table 2: Average costs

Building costs per Km	Duration	Maintenance costs per year and km	Costs per year and Km
226‘000 Euro	13 year	NA	10000 Euro

Decision: DB AG will use dampers only if the acoustic effectiveness can be increased, so that the dampers can achieve a noise reduction of 3 dB. In future trials the dampers will be tested on slab track and on high speed lines.

4.2.2.4. Finland

Dampers were tested in one location in southern Finland. No noise reduction could be observed. Finland is therefore not planning further trials for the time being.

4.2.2.5. France

In France dampers were tested on tracks and on bridges:

Tests on operational track

The acoustic performance of dampers were tested in 2004. Design requirements for the dampers included that the operation and maintenance of the track no be affected. The dampers were installed on an operated conventional railway line located in the south of France, near Pierrelatte (track equipment: bibloc concrete sleepers, UIC60 rail, 9 mm rubber rail pad high stiffness, ballast). The test site consisted of three adjacent sections of the down line track, each 200 m long: a reference section without dampers, a track section equipped with CORUS rail dampers and a track section equipped with S&V (SOCITEC) rail dampers.

The following types of measurements were performed: Direct rail roughness (homogeneous on the test section), track decay rates, trackside noise and track vibrations, on-board test train noise (underneath the wagon body) and vibrations (of the wheel sets) train wheels roughness. In addition simulations with TWINS where made. The results are given in Table 1Table 1.

Table 1: Acoustic effect (in dB) provided by dampers was measured at 7.5 m from the track center (April 2004)

Freight 100km/h	Stop train 145 km/h	IC 140 km/h	TGV 180 km/h
1.7 dB to 2.9 dB	2.3 dB to 2.7 dB	2.5 dB to 2.3 dB	2 dB to 2.9 dB

In 2005 additional noise measurement where made and the effect was higher (about 4 dB to 5 dB), however this was explained by a changes in the reference track.

The conclusion of this trial was that the efficiency of damper was confirmed as expected. The achieved overall noise reduction lies between 2 dB to 4 dB and is larger than 5 dB when considering the track contribution only.

Tests on the Gavignot bridge

The Gavignot bridge is a steel bridge without ballast with the rails mounted on wooden sleepers directly fastened to the steel deck plate. Initial TDR measurements were rather low. Rail dampers were mounted to test the acoustic effectiveness. Based on simulations an overall noise reduction of 5 dB to 6 dB were expected. Noise measurements, however, showed noise reductions of only 4 dB to 5 dB. On the other hand, TDR increased as expected. Because the rail is the main component responsible for sound pressure levels (SPL) increases above 100 Hz in steel bridges with direct fastening systems, rail dampers should become the standard solutions for noise mitigation in these cases in France. Even though this solution is less efficient than a sound barrier, it is cheaper and reduced noise in all directions.

4.2.2.6. The Netherlands

The Dutch railways are very active in the field of noise abatement. In 2001 a Innovation Program Noise (IPG) was started in The Netherlands, including numerous trials and model development. The main result of the program is that the TATA (continuous and discrete) and S&V dampers have been validated for an effect of 3 dB, i.e. they may be considered as measures which reduce noise by 3 dB in average situations. As a result, the dampers may be used on most lines as noise mitigation measures.
Fehler! Verweisquelle konnte nicht gefunden werden. summarizes the results of the different test done in The Netherlands. The measurements method follow a specific government regulation[4]. In the testing procedure it is assumed that the damper effect is dependent on the track roughness and therefore the results must be corrected to average Dutch track roughness. In contradiction to other testing procedures it must be noted that in The Netherlands TDR values, which are considered an important rating parameter of dampers, have only been measured in a few trials.

Table 2: This table gives the traffic categories used in Table 3 on noise effects.

Traffic mix categories used in trials	
Cat.1	electric passenger trains with cast iron block brakes
Cat.2	electric passenger trains with mainly disc brakes and additional cast iron block brakes
Cat.3	electric passenger trains with mainly disc brakes and additional (LL) block brakes
Cat.4	freight wagon with cast iron block brakes

[4] The regulation can be found at: http://www.stillerverkeer.nl/rmv/Wetgeluidhinder/Technical%20regulations%20for%20methods%20of%20measurements%20emisson.pdf

Cat.5	diesel electric trains with block brakes
Cat.6	diesel electric trains with disc brakes
Cat.7	metro and tram cars with disc brakes
Cat.8	electric passenger trains with only disc brakes / diesel electric light rail passenger trains
Cat.9	electric hi speed passenger trains with mainly disc brakes and additional block brakes on motor wagons
Cat. 10	electric light rail trains
Cat.11	freight wagon with LL or K block brakes

Table 3: **Summary of Dutch rail damper trials** (the roughness information is a reference to the original reports for those readers interested in this information).

Test site, Damper	**Construction parameters (ballast, rail, sleeper, clamps)**	**Traffic mix**	**Roughness**	**Measured noise effects Freight, Passenger)**	**Normalized noise effects (corrected for rail roughness, etc.)**	**Report/Comment**
Tilburg; Corus clip-on vs. Corus glued(continuous); 2007	ballasted track, UIC54 rail, concrete sleeper, James Walker FC9 rail pad, Vossloh SKL75 clamps	Cat. 1/Cat. 4/Cat.2/Cat. 8	Figure 6/App. 6	1.7-2.2 dB clip -on, 1.9 dB glued	3 dB - 2.9 dB glued	1
Rotterdam; Edilon, S&V,CDM ; 2006	ballasted track, UIC54 rail, concrete sleeper, James Walker FC897 rail pad, Vossloh ss 25-n clamps/near joint 953: wooden sleepers	Cat.1/Cat. 8	Figure 6/7	Measured results in appendices	Cat2: Edilon 1.4 dB, S&V,2.4dB, CDM 1.2 dB; Cat8: Edilon 1.2 dB, S&V,3.2 dB, CDM 0.9 dB	2
Zeeuwse lijn Krabbendijke; S&V (HSL) ,S&V(mod), Alom Tiflex; 2006	ballasted track, UIC54, concrete sleeper	Cat.1/Cat. 4/Cat.8	Figure 5.1	Table 5.1	Cat.1: S&V (HSL) 2.6 dB, S&V(mod) 2 dB, Alom 1.9 dB; Cat.4: S&V (HSL) 1 dB, S&V(mod) 0.8 dB, Alom 1.1 dB	3
Zeeuwse lijn Kapelle, Corus;2007	ballasted track, UIC54, concrete sleeper	Cat.4/Cat. 11 (Silent Freight), see table on page 7	Figure 5-1, Table 5-1, App. 9	1.8-3.2 dB		4
Zeeuwse lijn Kapelle; Corus prefab;2007	ballasted track, UIC54, concrete sleeper	Cat.4/Cat. 8/Cat.11	Figure 5-1, Table 2, Figure 5-2, table 3, App. 9	Cat.8 4.4dB, Cat.4 1.2 dB(60 km/h), Cat.4 2.3 dB (80km/h)	Cat.8 4.9dB, Cat.4 1.2 dB(60 km/h), Cat.4 2.3 dB (80km/h)	5
Krabbendijke, James Walker/Tiflex (modified); 2007	ballasted track, UIC54, concrete sleeper	Cat.1/Cat. 4/Cat.8	Table 1, Figure 2, App. 6	Cat.1 0.8dB (80), Cat.1 1 dB (123km/h), Cat.4 1 dB, Cat.8 2.9 dB	Cat.1 0.6dB (80), Cat.1 0.8 dB (123km/h), Cat.4 0.9 dB, Cat.8 2.3 dB	9

Tilburg; Corus clip-on; 2007	ballasted track, UIC54 rail, concrete sleeper, James Walker FC9 rail pad, Vossloh SKL75 clamps	Cat.1/Cat. 2	Figure 4, App. 4	2-3.1 dB depending on Cat. Average 2.7 dB	2.6-3.8 dB depending on Cat. Average 3.1 dB	10
Noise monitoring station Esch; Corus clip-on, S&V; 2009	ballasted track, UIC54 rail, concrete sleeper	6A) Cat.1/Cat. 2/Cat.4/Cat.8	6A):Table 17/9	S&V 0.1-3.7 dB, Corus -0.6-2 dB	Cat.1 S&V 1.8 dB, Corus 1 dB; Cat.2 0.3 S&V dB, Corus 1.1 dB; Cat.4 S&V -0.2dB, Corus 0.8 dB; Cat.8 S&V 2.5 dB, Corus 0.7 dB;	6A,6B. The measured noise reduction of both rail dampers is 1 to 2 dB less than earlier measurements during the Innovation Program Noise (IPG). Because of the relative high damping of the track, the rail dampers could be less effective

Reports:

1) Akoestische effectiviteit Corus raildempers, DeltaRail, 2007, commissioned by ProRail,

2) Bepaling Akoestische efectiviteit drie typenraildempers t.v.b HSL-Zuid, AEAT, 2006, commissioned by Ministerie van Verkeer en Waterstaad,

3) Meetrapport geluidreductie raildempers S&V en Alom, 2006, commissioned by ProRail,

4) Toetsing geluidreductie bronmaatregelen materieel en spoor, DHV, 2007, commissioned by ProRail

5) Toetsing geluidreductie Corus raildemper, DHV, 2007, commissioned by ProRail

6A) Meetonderzoek raildempers 2008 geluidmeetpost Esch, dBvision, 2009, commissioned by ProRail

6B) Akoestische karakterisering van het spoor bij Esch, M+P, 2009, commissioned by ProRail

9) Onderzoek geluidreductie raildempers JW Krabbendijke, Delta Rail, 2007, commissioned by DHV Ruimte en mobiliteit

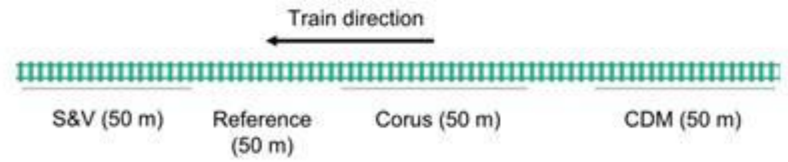
10) Akoestische effectiviteit Corus raildempers, Delta Rail, 2007, commissioned by VolkerRail.

4.2.2.7. Norway

In Norway dampers were only installed at one location in "Gamlebyen" close to Oslo central station. The dampers were mounted about 15 years ago. In this location in 2010 there are about 58 000 meters of train per day of which about 10 % freight. The only construction detail known is that there are mostly concrete sleepers. There are no exact noise measurement but the effect is expected at about 1-3 dB.

4.2.2.8. Sweden

In Sweden three different dampers (S&V, Corus (TATA) and CDM) were tested in Tjörnarp (2008-2009). In this trial the dampers were mounted on the track according to the following figure.



Pass by noise levels, TDR, and rail vibrations were then measured and the results from the damped sections were compared to those from the reference section. Before the trial the rails were grinded in order to achieve a comparable roughness for the different dampers. However a misunderstanding occurred and for some reason the section with the CDM dampers was not grinded and hence showed higher roughness than the others, so that no correct comparisons with CDM dampers could be made. The test track superstructure consists on UIC 60 rails, resilient rail pads and monobloc concrete sleepers on ballast. The track design is the standard design currently used in Sweden.

On the track both passenger trains (x2000 with velocity of 200km/h and Öresund trains with velocity of 160 km/h and partially damped wheels) and freight (with velocity of 90 km/h to 110 km/h) were in traffic.

Effects

The effects of the dampers on the overall pass-by noise are listed in table 6.

Table 4: Effects of tested Dampers (* indicates that no comparisons to the reference were possible).

	Freight	**Öresund**	**X2000**
CORUS	3 dB	2 dB	1.2 dB
S&V	2 dB to 3 dB	1.8 dB	1.9 dB
CDM	*	*	*

The increase in TDR compared to the track section without rail dampers is significant. However, the Corus and S&V dampers lead to a rather low TDR in the frequency range 1 kHz to 3 kHz (only 3 dB). *Rail* vibrations were also measured and for Corus and S&V there are reductions of about 7 dB to 10 dB. For CDM dampers the rail noise reduction is 1 dB to 6 dB.

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It should also be mentioned that the noise measured in the trial was dominated by frequencies around 2-2.5 Hz. This is most likely due to the presence of 2 cm wavelength grinding marks, strangely still remaining 15 months after the grinding . None of the dampers in the test were designed to be efficient at such high frequencies.

4.2.2.9. Switzerland

In Switzerland rail dampers were tested in three situations: Kerzers, on bridges and in an ongoing testing program:

Kerzers Trials

In Kerzers four different damper types (CORUS/TATA, S&V, STRAILastic, Vossloh) were tested in 2009. The dampers of one type were installed, noise levels were measured after which the dampers were removed and the next type was installed. As a reference noise measurements were undertaken before the trials were begun and at a location on the side of the instalment section. Pass-by sound levels, TDR and roughness were measured. The construction consisted of UIC60 rails, concrete sleepers, stiff rail pads (1100KN/mm static, thus high TDR is expected) and low roughness. A decrease of the sound pressure of about 2 dB to 3 dB for the “good” dampers was achieved. The lateral TDR increased 3.5 dB to 6.5 dB (averaged over frequencies) and the vertical TDR by 3.5 dB to 6.5 dB[5]. Problematic in this experiment was that the pass-by sound level differences depend on the reference measurement used; e.g. there is only a noise effect if the reference section on the side of the instalment section is used but not if the initial measurement is used. It also must be noted that the weather conditions differed from one trial to the next.

Bridges

In Switzerland rail dampers together with an elastic sleeper support were installed on two steel bridges, the Limmatbrücke and the Kleine Emmenbrücke,. On both bridges effects of 2 dB to 4 dB were obtained depending on the train type.

Current testing program

The goal of the ongoing testing program is a network wide cost and benefit analysis, a comparison of different damper types as well as an infrastructure related evaluation. The benefits are obtained based on a procedure developed by the Institute of Sound and Vibration (ISVR) of the University of Southampton and discussed in the STARDAMP project. It consists of two parts based on the theoretical idea that the TDR of a track with dampers (total TDR) can be obtained by summing the TDR of the track (field TDR) without dampers and the TDR of a free rail with dampers (free TDR). A free rail is a softly layered (e.g. on springs) rail not bound by sleepers and uncoupled to the ground in the range of the most interesting frequencies and thus is able to vibrate freely. The actual noise reduction can then be calculated using TWINS based on the total TDR and assuming values for the other relevant parameters. (e.g. roughness, rail wheel interaction, train velocity, train types etc.). The testing program is summarized in Figure 9.

[5] These dB values are **not** noise reductions.

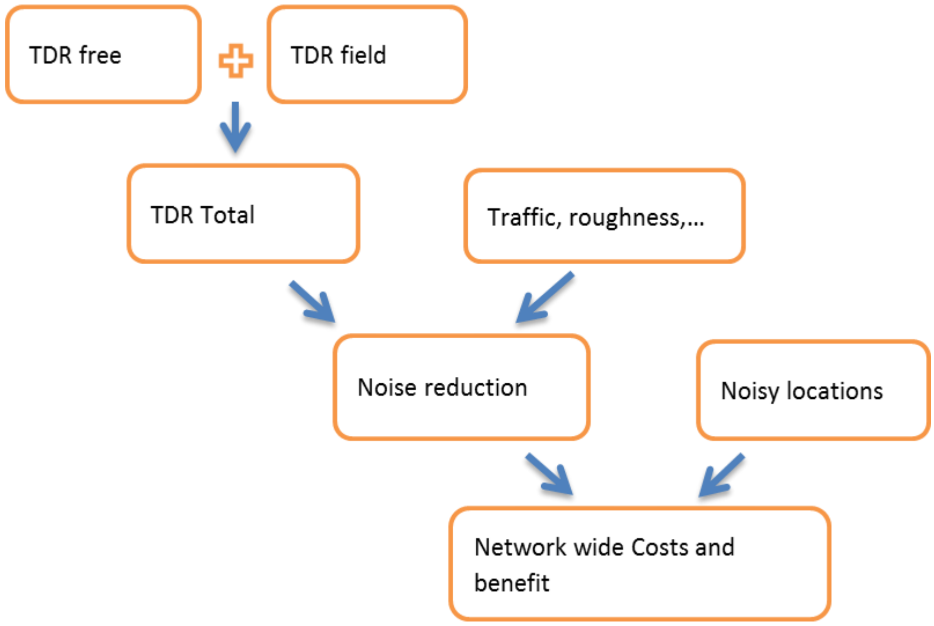

Figure 9: Diagram of testing program.

As of May 2012 the free TDR have been measured and the field measurements have begun. The cost benefit analysis should be complete by the end of 2013.
In parallel the four types of dampers will be installed at a critical location in terms of infrastructure and the behaviour of the dampers will be observed during three years. TDR will be measured before and after the installation and rail roughness will be monitored regularly. This part of the trial should be complete by the end of 2015.

4.2.3. Conclusions

The results are summarized in Table 7.
Based on the results available the following conclusions can be made:

- There is a large variability in the results ranging from small increases in noise to a maximum noise reduction of usually about 3 dB.
- The effects of dampers are influenced by many parameters such as construction (rail pad stiffness) or traffic. However in many of the results these parameters were not measured. Therefore it is difficult to compare the results.
- Network wide cost-benefit analyses were not undertaken. The ongoing Swiss project is the first to attempt this.
- The STARDAMP project and the ongoing Swiss trials are the first systematic approaches to the problem.
- Many questions are still unanswered (e.g. the effect of dampers on rail roughness). More investigation of rail dampers is an important prerequisite before large investments are made. It is strongly urged that the railways cooperate and design experiments allowing all critical parameters to be included.

Table 5: **Summary of damper trials.**

Damper (D): 1)S&V; 2) TATA; 3) Vossloh; 4) STRIALastic; 5) CDM; 6)Other

Track: Rail, Sleeper, Pad stiffness. Green: positive comments on dampers, yellow: no comment, red: negative comments in report.

Country	Description	Track	Damper	Traffic	Roughness	TDR	Noise effect	Comments	Report
Austria	Trial "Konzertkurve" near	UIC60, wood sleeper,N/A, turn	1,2,3	Mixed	From low to high. Measurement to study the roughness growth	Increase of about 4dB/m between 800Hz to 1.6kHz	0.5 dB to 3.5 dB depending on train and damper	After mounting of the dampers a fast increase of the roughness has been observed. Different roughness levels made the comparison of sound level difficult	1,2
Czech Republic	3 trial sections	UIC 60, S49+wooden sleepers	2,3	Mixed, 40-70 % cargo	under the TSI limit (Poděbrady), 2 other sections N/A	N/A	0,5-4 dB	Dampers seemed to be more promising than they really are. The efficiency of Vossloh dampers (2009) has been slightly decreasing (with no particular reason).	
Germany	Differents Trails	Sleeper and ballast	N/A, 5 differtent types	Mixed	Measured, not reported	measured, not reported	2 dB	Negative decision to use dampers as Noise mitigation Measure	8
Finland	Trial	N/A	N/A	N/A	N/A	N/A	About 0 dB	NO details of the trial are known. Insufficient knowledge for any conclusion.	N/A
France	Trial Pierrelatte	UIC60,bibloc concrete, high	1,2	N/A	homogeneous on the test track	increase	2 dB to 4 dB	Satisfaction with the solution	3

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France	Bridge, Gavignot	UIC 60, wood sleeper, N/A	D1	N/A		High increase	3 dB to 4 dB	Satisfaction with the solution	4
The Nether-lands	Many trial and tests	UIC54, concrete sleeper	1,2,3,4, 5,6				3 dB	Details in The Netherlands subsection.	
Norway	Mounted in Gamlebyen 15 year ago	Concrete sleep-er, N/A,N/A	N/A	Mixed 10% freight	N/A	N/A	1 dB to 3 dB	No details of the trial are known. Insufficient knowledge for any conclu-sion.	N/A
Sweden	Trial Tjörnarp	UIC60, Concrete Monobloc, N/A	1,2,5	Mixed	Ground be-fore trial		Effects for D1,2: 2 dB to 3dB freight 1-2dB passenger	For damper 5 no attendible results.	5
Switzer-land	Bridges Limmat, Klein Emmen	Together with elastic sleeper	1	Mixed	N/A	N/A	2 dB to 4 dB	SBB is satisfied with the re-sults	6
Switzer-land	Trial, Kerzers	UIC60, concrete, high	1,2,3,4	Mixed, special for the trial	Low	Signifi-cant increase	2 dB to 3 dB		7
Switzer-land	Current trial	Mostly UIC60	1,2,3,4					The trial is in process	N/A

Reports:
1) *Praktische Erfahrungen mit Schienenstegbedämpfungen bei den ÖBB*, Bernhard Knoll ÖBB Infrastruktur Bau AG
2) *Vossloh-Absorber Endbericht2009*, psiA-Consult, 2009, commisioned by ÖBB Infrastruktur Bau AG
3) *Complete assessment of rail absorber performances on an operated track in France*, F. Létourneaux, F. Margiocchi, F. Poisson, SNCF
4) Franck Poisson Florence Margiocchi, *The use of dynamic dampers on the rail to reduce the noise of steel railway bridge,* Elsevier, 2006
5) *Quiet City Transport, Performance report of applied measures – Malmö*, Part 1, 2008
6) *Pilotprojekt „Schwingungsabsorber bei Stahlbrücken"Brücke über die kleine Emme,* Planteam GHS AG, 2009, commissioned by SBB
7) *Feldversuch Schienenabsorber BLS 2010*, PROSE, 2010, commissioned by Schweizerische Bundesamt für Umwelt
8) Schlussbericht: *Innovative Maßnahmen zum Lärm- und Erschütterungsschutz am Fahrweg*, DB Netz AG, 15.6.2012

4.3. Acoustic rail grinding

4.3.1. What is acoustic rail grinding?

Railway noise creation depend to a large extent by the sum of rail and wheel roughness as well as corrugation. Therefore a smooth rail is an important element in reducing railway noise.
Ideally, the roughness (and corrugation) should be controlled by avoiding its formation in the first place. Based on current knowledge, rail grinding is the main method to achieve a smooth rail. As mentioned earlier, regular (maintenance) grinding is carried out to remove corrugation and to restore the transverse profile of the rail. If acoustical roughness is to be removed as well a special procedure called acoustic grinding must be used usually undertaken separately from regular grinding. Important to remark is that the roughness (as the corrugation) is not a time invariant propriety of rail, in general it grow with the time, thus noise reduction effects due to acoustic grinding are limited in time.

An appropriate procedure for the acoustical grinding will then consist in two steps; the monitoring of the roughness (acoustical) and the grinding itself which must be repeated as soon as the roughness reaches a critical value. A sketch of this procedure is illustrated in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

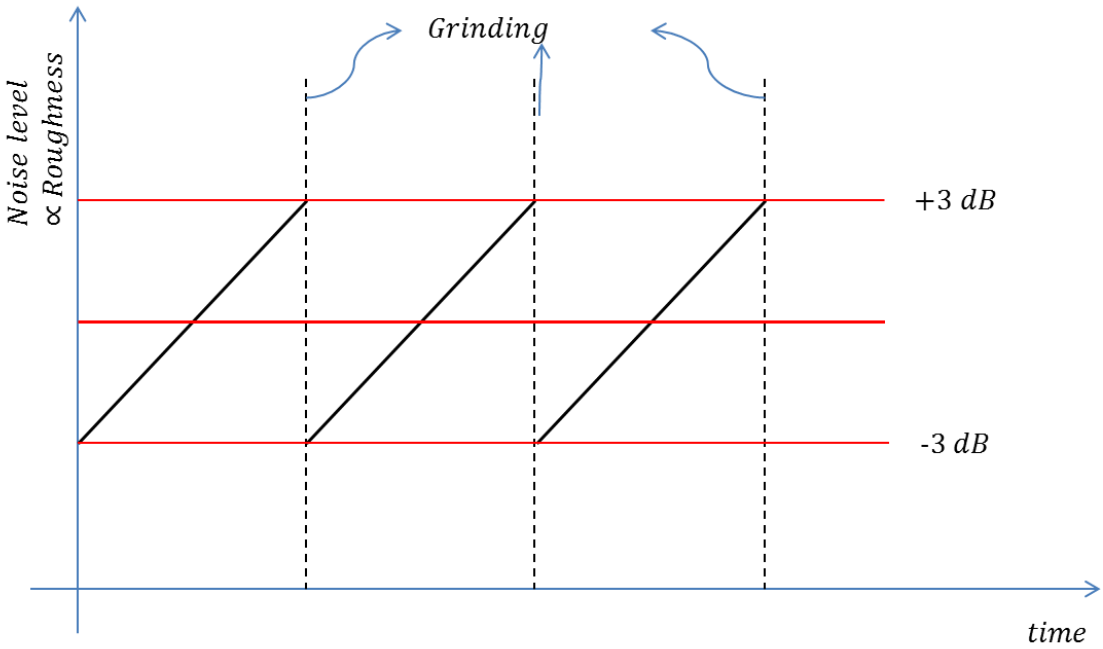

Figure 10: Evolution in time of the rail roughness by applying acoustic grinding procedure. In this model linear grow of roughness and proportionality between noise and roughness are assumed. The BüG procedure in Germany is based on this model and grinding is done when the noise level is exceed by 3 dB.

The noise effect of grinding is maximal after the grinding procedure (usually between two and four weeks after grinding). In general, a very rough track will have a larger noise mitigation potential with grinding. After some time (with the growth of roughness) the initial values are reached again and the whole procedure is repeated. The linear roughness growth in this illustration is an ideal situation; In

reality there is insufficient knowledge concerning roughness growth. Therefore regular monitoring is necessary.
The lowest point reached in the graph depends on the quality of the grinding procedure. The smoother the rails the larger the noise reduction.

The usual monitoring procedure for corrugation, normally undertaken with a diagnostic train, is too imprecise to detect those anomalies relevant for acoustical roughness. A different procedure must be used and two substantially different methods have been developed: In the *direct* method a small device rolls on the surface of the rail and measures all irregularities. This is a slow but precise method, useful for short sections but not for an entire network. In the *indirect* methods roughness is either calculated based on noise measurements or on axle acceleration. These methods are less precise but because they can be mounted on moving trains they are suitable for network wide measurements.

The different monitoring and grinding procedures are described in Table 6.

Table 6: Overview of monitoring possibilities

	Acoustic Grinding	**Normal Grinding**
Monitoring	5mm < Wavelength < 20 cm	2 cm < Wavelength
Direct monitoring	Precise but slow.	Implemented on train fast
Indirect monitoring	Noise measurement, fast (used in Germany and NL)	Not known, Vibration measurement

4.3.2. Experience with rail grinding

4.3.2.1. Germany[6]

Since 1998 the German railways have implemented special acoustic grinding procedure called "Besonders überwachtes Gleis" (BüG). In this procedure about 1000 km of the network are monitored with the roughness-measuring SchallMessWagen (SMW). As soon as the rail roughness reaches a certain limit value, the rails must be ground within a given time. In those sections where this procedure is implemented a nominal 3 dB noise creation reduction is allowed by the railway administration.

In the BüG procedure (see **Figure 10**) a track is first assigned a specific noise value. This value is given in dB and depends among other things on construction parameters and traffic. The track is then monitored every six months with the SMW. When the measured value exceeds the track specific value by 3 dB the rail must be ground and if it exceeds the value by 2 dB grinding must take place within 10 months.

The monitoring of the roughness is done indirectly with the above mentioned special train called Schallmesswagen (SMW) equipped with noise measurement wagons. These wagons are equipped with a microphone at the center of a special bogie without brakes and very smooth wheels. In this

[6]B.Asmussen et al. *Status and prespectives of the "Specially Monitored Track*", DB,200?.

case the noises measured is not influenced by wheel roughness and therefore rail roughness can be implied.

Two methods are used for acoustic grinding:

- Planing/Milling followed by grinding with oscillating stones
- Grinding with discs and then with a belt sander

In both cases the grinding speed is about 1.2 km/h.

Problematic with the BüG is that the assumed noise reduction of 3 dB is usually not reached in reality. This may be because of track specific values that where defined at too low a level, that the roughness growth is too different from the time linear increase assumed or the grinding is not accurate enough..

4.3.2.2. The Netherlands

In The Netherlands the required grinding results are specified in terms of noise reduction: Grinding e.g. must achieve an average noise reduction of 2 dB for disc-braked vehicles at a speed of 120 km/h. Since the rail roughness is not an invariant quantity the interval between grinding actions should be chosen in such as way that the average noise reduction is 2 dB. Experience has shown that rail grinding is usually necessary every two years. Grinding is done with SPENO machines.

Like in Germany rail roughness is monitored indirectly with the help of noise measurement wagons and using the principle that rail roughness directly influences the rolling noise of trains The system used in The Netherlands is called ARRoW. Although the measurement configuration is different than the SMW, comparisons[7] of both systems have shown that they are equally suitable for indirect rail roughness monitoring.

Test[8] have also be done with prefabricated ground rails with satisfactory results of about 6 dB less noise compared with normal fabricated rails.

The effect of prefab grinding is not monitored afterwards. So we don't know how long the effect stays. But it is likely the rail roughness growth will be comparable with the track under normal conditions. .

New developments

Since 1 July 2012 roughness spectra for normal lines (<200 km/h) and high speed lines (>200 km/h) are added to the Dutch calculation scheme. This development makes it possible to calculate with general values for noise reductions of acoustic rail grinding. Since the noise ceilings are in force (also

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[7] *Indirect rail roughness measurement, M+P, 2008,* commissioned by ProRail

[8] Measurment report, *Rail roughness of railway track with prefab grinding, M+P, 2008,* commissioned by ProRail

Other useful reports:

-Rail grinding and damping- translated version, IPG projects2.2.1 and 2.2.2, ProRail, 2005

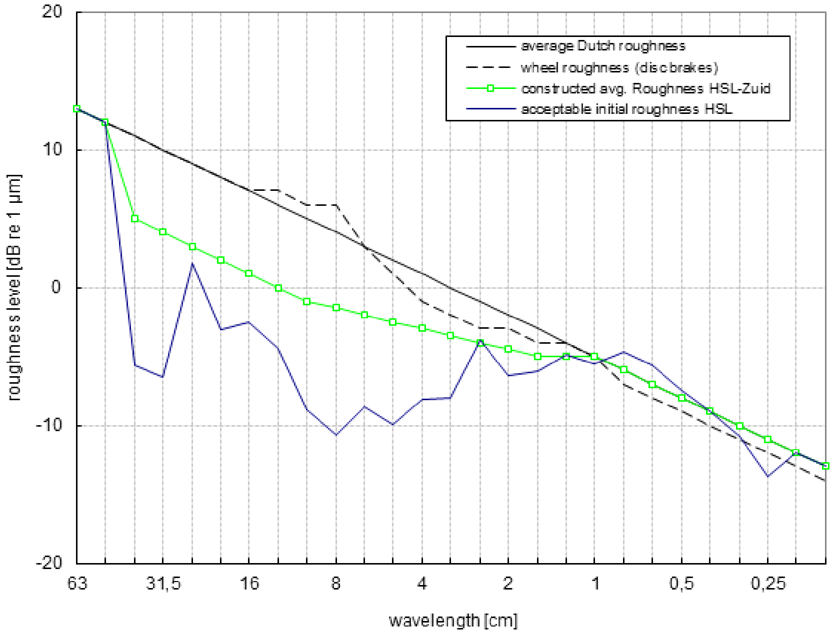
- *Specifications for the IPG rail grinding monitoring experiments,*M+P, 2007

- AEJ Hardy and RRK Jones, *Rail and wheel roughness implications for noise mapping based on the Calculation of Railway Noise procedure,2004, committed by Defra* starting July 1st, 2012) it is expected that acoustic rail grinding will become a serious measure. This is the first step, implementation of acoustic rail grinding in maintenance procedures is the next step.

The roughness spectrum for normal lines is based on four years monitoring of rail roughness on the Dutch test track. During these four years the track was ground twice according to acoustical specifications. See for more details the report[9].

The roughness for high speed lines is based on a few years of monitoring and maintaining a minimum rail roughness on the Dutch high speed line by acoustic rail grinding. See the green line in the Figure 11.The goal is to maintain the green line which corresponds with roughness spectrum in the Dutch calculation scheme.

Figure 11: High speed roughness spectra



4.3.3. Conclusions

Only two countries – Germany and The Netherlands – have implemented acoustic rail grinding procedures. In Germany the procedure allows a noise reduction of 3 dB, regardless if this is achieved in practice or not while in The Netherland specific noise reduction aims are defined.

9 Akoestisch onderzoeck, Opstellen railruwheidsspectrum voor akoestisch slijpen, M+P, 16.4.2012, commissioned by ProRail

There are currently no detailed network wide cost benefit analyses comparing grinding with other measures. It is suggested that these are undertaken, best in a cooperative approach by different railways.

5. Mitigation measures against noise propagation

5.1. Low height noise barriers

5.1.1. What are low height noise barriers?

Low height noise barriers are barriers that are placed closer to the railway and have a lower height than normal. Normal barriers are usually built at a distance of about 4 m from the rail axis and have a height which varies between 1.5 m and 4 m above the railhead. So called low height noise barriers are installed at about 1.70 m distance from the axis of the nearest track and have a height of about 0.5 m to 1m.

Figure 11 illustrates a typical situation with two possible barriers of different heights and at different positions. In the sketch source and measure point are denoted by the small circles.

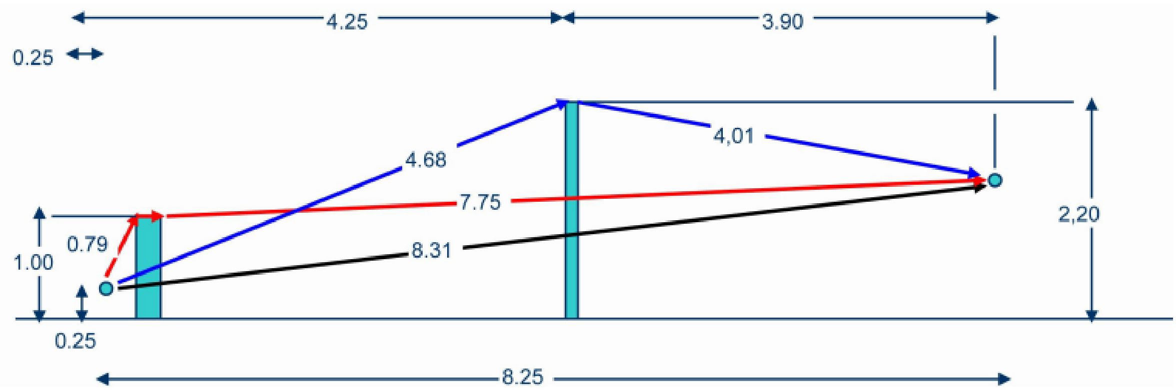


Figure 12: Geometric comparison of low height barrier close to rail with the usual configuration at about 4 m. The noise reduction is about the same in both situations.

A common model used to predict the noise reduction of a barrier depends on the additional distance passing over the barrier that is required from the source to the reception point. In Figure 11 the length of the red or blue lines are compared with the length of the black line – in this particular situation giving the same noise reduction.
For an accurate acoustic comparison of low height and normal barriers the geometry of source and reception points have to be considered in detail and the effect will depend on the situation, however the simple considerations done are enough to argue that the acoustic performance of the two solutions could potentially be similar. A critical issue is that if there are many parallel tracks, small barrier on the side looses its efficiency for those tracks further away from the barrier. This can be solved - if there is sufficient space – by placing low height barriers between the tracks, in this case is then the low barrier more effective than the high one.

Overall, the noise reduction of a low height barrier lies between 5 and 11 dB. This value can be increased, if shrouds are used to cover the wheels. The total noise reduction then depends on the gab between the shroud and the low height barrier[10]. This report, however, only considers the barriers themselves.

5.1.2. Why are low height barriers controversial?

Acoustically the idea of lower barriers nearer to the noise sources makes sense. In certain situations there may even be an increase in noise reduction, especially then, when low height noise barriers can be place between tracks. A further advantage is, that there is less obstruction of the view, both from inside the train as well as for lineside inhabitants.

The controversy stems mostly from a maintenance and construction point of view. Here are some of the reasons stated that may give problems when low height barriers are used:

- Even with a small foundation there may be conflict with drainage and certain construction elements close to the track. Maintenance more difficult and time consuming: more and longer night closures which contradict increasing capacity
- Problems may occur in case of accidents e.g. because of increase in evacuation time
- Increased risk for staff. Low barriers are for staff working on the rail a difficult obstacle to pass up in the case of train pass by.
- Costs can be similar to normal height barriers if low height barriers are required between tracks.

5.1.3. Product solutions

Several different low height barriers have been tested. A selection of products is listed below:

5.1.3.1. Asamer rubber technolgy (ART)

[10] EU Project „Silent Track“, 1996 – 1999.

Figure 13 (left): Trials in Melz with ART barrier.
Figure 14: fastening on sleeper of ART barrier.

The ART barrier does not have a foundation. The ART are tested in trial in Austria at Melz. No other experience are known about this product

5.1.3.2. Zbloc

Figure 15 (left): Zbloc barrier.
Figure 16: Steps for emergency exit.

Since 1996 Zbloc produces low height barriers in Sweden. There are meanwhile many reference projects in Sweden build with Zbloc elements. The protection wall is made fibre reinforced concrete and an absorber consisting of thin matting material made of granulated rubber. The height above the top edge of the track is 73 or 53 cm and are mounted at distance of 1.78 m from the middle of the track. A small foundation is required. The barriers provide steps an emergency exists to address the security issues. .

5.1.3.3. FERRONDO silenzio forte

The low height noise barrier “FERRONDO Silenzio Forte” consists of vertical three-chamber gabions with a concrete core and an absorber mat in combination with a special lava rock filling. The outer chamber can be custom designed in a variety of looks. The gabions have a maximum height of 76 cm above the top edge of the track and a distance of 1.78 m from the middle of the track (Figure 17). Since the gabions are filled with rocks, the impact on the landscape is smaller than with many other barrier types. Until now, the FERRONDO Silenzio Forte has only been tested in Germany.

Figure 17: Ferrondo Silenzio Forte barrier.

5.1.3.4. Soundim Rail (Finland)

Soundim Rail barrier is inclinable and longitudinally adaptable with facilitates maintenance. The foundation is the cable box at the same time. This barrier type has been tested in Norway and Finland.

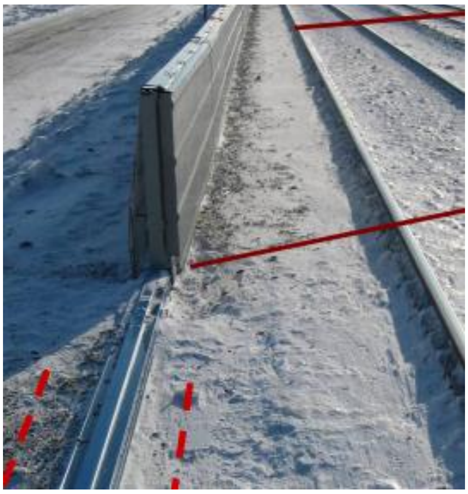


Figure 18(left): Soundim Rail barrier.
Figure 19: Foundation and cable box.

5.1.3.5. Brens Barrier (Czech Republic)

Low noise curtain BRENS BARRIER is formed by a parabolic part in the noise absorbing layer made of recycled rubber. The technical solution includes functional areas to ensure the safety and evacuation of passengers. Prototype parts were made of concrete without steel reinforcement and inserted into the manufacturer’s siding rails (see Figure 20).

Figure 20: Low height noise barrier BRENS BARRIER – factory railway track ZPSV – Čerčany

Also, prototype parts of rail noise absorber called BRENS ABSORBER were made in order to increase sound absorption of the rails. Laboratory measurements of noise attenuation were taken. Noise reduction achieved in the laboratory for the whole system was of 14 dB. Results for the barrier alone are not known.

5.1.4. Railways experience with low height barriers.

The experience is first described country by country after which the noise effects are summarized at the end of the chapter.

5.1.4.1. Austria

In Austria ÖBB are currently testing the ART barrier at Melk. The resulting noise effects are between 5 dB to 6.7 dB (measurement point: 25 m distance, 1-2-3-5 m high). The barrier has also fulfilled the winter tests.

5.1.4.2. Czech Republic

In 2010, the Czech company PROKOP RAIL ended development of new features with the designation BRENS. At the same time legislative adjustments were made to national standards so that these new features can be used in the SŽDC network. Preparations were undertaken for setting up a test section equipped with a low noise prevention wall before the beginning of 2013. The noise level of this selected section has had a negative impact for a long time and local conditions are suitable for the installation of low height noise barrier. The low height noise barrier supplied by a Czech manufacturer (Brens Barrier – ŽPSV) is likely to be used.

Application of track absorbers BRENS ABSORBER on the test section is not planned yet due to the economic opportunities.

5.1.4.3. Germany

In Germany in the context of the Konjunkturprogramm II „Erprobung Innovative Maßnahmen zum Lärm- und Erschütterungsschutz am Fahrweg“ seven different low height noise barriers were tested at nine different locations. Noise measurements were undertaken at eight locations. The seven different products differ in construction and height (55 cm and 74 cm). For more information and photos please see the report[11].

In all locations noise levels with and without barrier and with noise source on the closer and further trackl were measured (at 25m distance). The averages of the obtained differences are reported in Table 7 for different situations; 55 cm or 74 cm height, with or without a barrier between the track and different traffic types.

Table 7: Measured (25 m distance) noise effect of low height barriers in Germany

Noise source	**Reduction for track closest to barrier (dB)**			**Reduction for track furthest from barrier (dB)**		
Measurement point height	3.5m	6.3m	9.1m	3.5m	6.3m	9.1m
Barrier height 74 cm, single barrier						
NV/IC/ICE	7	6	5	4	1	0
freight	5	4	3	4	1	0
Barrier height 55 cm, single barrier						
NV/IC/ICE	2	2	2	2	1	0
freight	3	2	2	1	0	0
Barrier height 74 cm, with barrier between the track						
mixed	6	5	4	5	2	2
Barrier height 74 cm, with barrier between the track						
mixed	3	2	2	2	2	1

The cost of the barrier varies between 1.1 and 1.9 Mio Euro pro km. The differences are explained by different construction types. Costs that arise due to increases in maintenance are not known as of yet.

Germany plans to consider low height barriers in the future alongside regular barriers.

5.1.4.4. Finland

In Finland the Soundim barrier was tested. The measured noise reduction is approximately 10 dB. No problems with snow removal or track maintenance were reporting. The program is still ongoing and more detailed information is expected at a later date.

5.1.4.5. France

In France only theoretical studies on the shape of low height barrier are known. The conclusion is that the shape is an important parameter for the effectiveness of the barrier.

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[11] Schlussbericht: *Innovative Maßnahmen zum Lärm- und Erschütterungsschutz am Fahrweg*, DB Netz AG, 15.6.2012

5.1.4.6. Netherlands

In 1999 tests and study were undertaken on the acoustical effects of low noise barriers but the results are missing. The Netherlands are organizing a pilot to use low height barriers in a specific project. This pilot will include testing by noise measurements and calculations. If all goes according to plan a low height noise barrier will be built. Not known yet is which type will be used. The pilot will also address implementation and cost effectiveness issues besides.

5.1.4.7. Norway

In Norway a pilot project was realized just outside the Central Station in Oslo. Measured sound reduction by the various barriers in these pilot projects was typically 7 dB to-11 dB (measured 2 m over the ground, 10m from track centre).
The project was satisfactory in terms of acoustic performance and did not show any important safety and maintenance problems. The National Rail Administration therefore approved the use of low height barriers close to the track. On the renewed line Sandnes-Stavanger 7 km of close track barriers were subsequently installed in various locations along the 14.5 km long section. The barrier elements are produced with reinforced concrete. The absorptive elements on the inside consist of a 50 mm of rock wool, covered with a perforated steel plate (they have a similar design to Zbloc).

Most inhabitants along the railway section were very satisfied with the chosen solution: Their view of the ocean remained intact while at the same time reducing noise significantly. All noise limits required of the project were satisfied.

5.1.4.8. Sweden

Sweden is with Norway the only country which uses low barriers in a extended way. Since 1996 the product used is the Zbloc. In total 8.3 km of low height barrier have been installed. The influence of maintenance has not been reported on – the information available concerns the acoustic performance only.

The acoustic tests were done by Banverket at a location near Stockholm from 2005-2008 on a track with high density of passenger (X60, X12,X40,IC) trains and some freight traffic. The results showed that the noise reduction depends on the train type: For X12 and X60 trains the measured noise reduction was 7/9 dB, respectively. The barrier was less efficient (4 dB to 6 dB) for the X40, IC and freight trains.
It is expected that bogie shrouds could increase the efficiency.

5.1.4.9. Switzerland

In Switzerland no practical trials were undertaken. A detailed feasibility report written in 1995 showed that there were too many problems with maintenance and security so that low height barriers were not pursued further.

5.1.5. Conclusions

There is not much information available on low height noise barriers to date and the trials are mostly not precise enough to undertake a final conclusion on the issue. The basic arguments are still the same: From an acoustical point of view low height barriers are similar to normal barriers and they have the advantage of better fitting into the landscape. On the other hand, there is not yet enough experience to satisfactory address maintenance and security questions. Some countries (e.g. Norway) do not report problems, others (e.g. Switzerland) are not pursuing the issue because of these concerns. Table 8 summarizes the experience obtained to date.

Table 8: **Summary of the experience obtained to date**

	Theoretical	Trials/theoretical studies	extended use	Acoustic effect	Encountered (or not) problems	Report/Remarks
Austria	NA	ART (current)/NA	No	5 dB to-7 dB	No problem in winter	NA / No foundation
Czech republic	Laboratory tests	BRENS BARRIER laboratory tests	No	14 DB	NA	NA/ Trail test planned
Germany	NA	8 locations,	4.5 km	7-2 dB	NA	8) Approved measure now
Finland	NA	Soundim (current)/NA	NA	10 dB	Ok with snow clearing	1/Foundation figures a cable canal. Barrier can be folded.
France	Yes(design studies)	NA/Theoretical	No	NA	NA	
Netherlands		Ongoing pilot test				
Norway	yes	self developed (similar Zbloc)/ NA	6.3 km	7 dB to 11 dB	NA	2
Sweden	NA	Zbloc/NA	Zbloc total 8.3km	4 dB to9 dB	NA	3
Switzerland	Yes(feasibility report)	N/Theoretical	No	NA	NA	4/Not pursued due to maintenance and security issues

Reports:
1) Meeting Presentation,*Noise Mapping Low height barrier Finnish experiences*, Erkki Poikolainen, 2011
2) *On the extensive use of close-track noise barriers in a Norwegian railroad project*, Enno Swets, Euronoise, 2009,
3) *Quiet City Transport, Performance report of applied measures – Malmö*, Part 2, 2008
4) Analysebericht, *Gleisnähe Lärmschutzwände*, SBB, 1995
5) Schlussbericht: *Innovative Maßnahmen zum Lärm- und Erschütterungsschutz am Fahrweg*, DB Netz AG, 15.6.2012

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6. General conclusion

This report was undertaken to collect the studies undertaken in Europe on three different and controversial noise mitigation measures: Rail dampers, rail grinding and low height noise barriers. The sum of the collected results show, that the controversy still remains, despite the studies undertaken. The conclusions can be summarized as follows:

Rail dampers:

- There is a large variability in the results ranging from small increases in noise to a maximum noise reduction of usually about 3 dB.
- The effects of dampers are influenced by many parameters such as construction (rail pad stiffness) or traffic. However in many of the results these parameters were not measured. Therefore it is difficult to compare the results or to use the results from one situation to predict the effects in another one.
- Network wide cost-benefit analyses have not been undertaken to date. The ongoing Swiss project is the first to attempt this.
- The STARDAMP project and the ongoing Swiss trials are the first systematic approaches to the problem, which measure all relevant parameters. The results of these projects still outstanding.

Rail grinding:

Only two countries – Germany and The Netherlands – have implemented acoustic rail grinding procedures. In Germany the procedure allows a noise reduction of 3 dB, regardless if this is achieved in practice or not while in The Netherlands specific noise reduction aims are defined.

Lacking are network wide cost benefit analyses. It is suggested that these are undertaken, best in a cooperative approach by the railways.

Low height noise barriers:

There is not much information available on low height noise barriers to date and the trials are mostly not precise enough to undertake a final conclusion on the issue. The basic arguments are still the same: From an acoustical point of view low height barriers are similar to normal barriers and they have the advantage of better fitting into the landscape. On the other hand, there is not yet enough experience to satisfactory address maintenance and security questions. Some countries (e.g. Norway) do not report problems, others (e.g. Switzerland) are not pursuing the issue because of these concerns

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