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Table of contents

List of abbreviations

AEG	General Railway Act (Allgemeines Eisenbahngesetz)
BImSchG	Federal Immission Control Act (Bundes-Immissionsschutzgesetz)
BImSchV	Ordinance on the Implementation of the Federal Immission Control Act (Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes)
BSN	Federal Association of Regional Railway Authorities (Bundesverband SchienenNahverkehr e.V.)
DAK	Digital automatic coupling (Digitales Automatische Kupplung)
DZSF	German Centre for Rail Transport Research (Deutsches Zentrum für Schienenverkehrsforschung)
EBO	Railway construction and operating regulations (Eisenbahn-Bau- und Betriebsordnung)
EU	European Union
SGV	Rail freight transport (Schienengüterverkehr)
SPFV	Long-distance passenger rail transport (Schienenpersonenfernverkehr)
SPNV	Local rail passenger transport (Schienenpersonennahverkehr)
TSI	Technical specification for interoperability
WHO	World Health Organization

1 Introduction

Rail transport generates a relevant proportion of traffic-related **noise pollution**. Along the main railway lines in Germany, 4.2 million people are exposed to night-time noise levels above the World Health Organisation (WHO) recommended exposure limit of 45 dB(A). In addition, there are people exposed to noise on the other lines in the network. In some cases, the WHO recommendations are exceeded by more than 20 dB(A). According to surveys by the Federal Environment Agency, around 34% of people felt "at least somewhat" disturbed or annoyed by rail traffic noise in 2020 and 5% of people even felt "severely" or "extremely" disturbed or annoyed.

At the same time, the railway is expected to play an important role in the **mobility transition**. Their transport performance is set to increase, but this will further increase noise pollution if noise-reducing measures are not taken at the same time. This will also jeopardise the political achievability of the transport transition goals, as the resistance to the expansion of the rail network or the reactivation of routes is primarily due to the noise problem. Furthermore, the transition to sustainable transport is not compatible with a means of transport that generates high noise emissions or requires the use of noise barriers.

Section 1.3 of the report provides **the previous noise policy** with regard to rail transport. The successes achieved in recent years (abolition of grey cast iron brake blocks for freight wagons, progress in noise prevention and noise remediation, creation of basic instruments such as noise mapping and noise monitoring) are offset by the fact that there is still no comprehensive approach to noise policy. Emission limits[1] only exist for new vehicles (the EU's TSI Noise), not for used vehicles and not for infrastructure. Immission limit values only exist for new construction or significant changes to railway lines – although changes to the operating programme of a line (number and type of trains) or the noise emission limit values are not treated as significant changes.

The aim of this report is to develop a comprehensive noise protection concept for rail transport. To this end, **all types of rail transport** are considered, i.e. not only rail freight transport (SGV), but also regional (SPFV) and local rail passenger transport (SNPV) and the **infrastructure**. There have long been calls for more noise reduction at source. With this objective in mind, noise reduction measures and instruments are identified for all areas, whereby **measures** are of a technical or operational nature and must be implemented by the players in the railway sector, while **instruments** include all forms of political influence on these players. The report's **recommendations for action** are aimed both at a reform of the general legal and institutional framework of noise policy and at specific instruments tailored to the implementation of certain measures or those from a group of possible measures. Cost-effective measures are favoured, and thus also **measures at source** and corresponding instruments.

On the other hand, one problem with noise policy to date is that it has shown too strong a tendency to erect **noise barriers**. This is explained in section 1.3.3 of the report and critically analysed in an excursus (section 1.3.5). The excursus also points out the contrary effects of **tunnels and speed limits** on the functionality of the railway when these are demanded as standard measures against noise.

[1] While the generation of noise (e.g. by a passing train) is called *emission*, the impact of noise (e.g. on a resident living near a railway line) is referred to as *immission*. See Chapter 2 of the report.

2 Fundamentals of noise and noise reduction in rail transport

Sections 2.1 and 2.2 of the report describe the basic objective parameters and subjective factors of acoustics. **The logarithmic nature** of human hearing means that a doubling of the traffic volume leads to an increase in the average noise level of only 3 dB(A). If, for example, noise-reducing measures succeed in reducing the noise emissions caused by a passing train by 6 dB(A), a noticeable noise reduction would occur even if the number of trains doubled. This example illustrates that the desired increase in rail traffic does not necessarily have to stand in the way of noise reduction.

Differences in the volume of different sound sources are amplified by the logarithmic nature of hearing, so that the loudest sound source often strongly dominates perception. Depending on the speed of a train, different noise sources or types of noise dominate. At standstill or at low speeds, **engine noises** emitted by fans, compressors etc. dominate. At medium and higher speeds, rolling noise dominates, and at very high speeds, aerodynamic noise dominates. Added to this are curve, braking and other noises. **Rolling noise** is of particular importance as it dominates in a wide speed range in which the trains are predominantly travelling. The rolling noise is excited by the joint roughness in the wheel-rail contact. For low excitation, both wheel and rail roughness must be low.

This results in various **points of attack for noise-reducing measures.** The wheels of passenger trains – **SPFV and SPNV** – are already relatively smooth due to the disc brakes used there, so that the rolling noise is dominated by this in the case of high rail roughness and can be used here to reduce noise. In the vicinity of railway stations, there is also the noise of the power unit and brakes, which can be a problem, especially on **regional rail services** due to the frequent stops. The door warning sound and the processes involved in night-time parking also pose problems. The wheels are not as smooth as in passenger transport, which means that both the wheels and the rails need to be smoother to reduce rolling noise. In addition, the wheels often have flat spots that cause banging noises. The locomotives generate both unit and rolling noise, which can be minimised. With regard to the track, the track decay rate plays an important role in addition to the rail roughness, as this characterises the sound radiation of the track.

The **political and legal instruments** that can be used to minimise noise are divided into the following categories:

- Planning instruments
- Instruments of direct behavioural control in the form of requirements and bans (e.g. emission and immission limits, technical approval regulations)
- Instruments of indirect behavioural control, in particular economic instruments (e.g. financial support, noise-dependent track access charges)
- Operational organisational instruments
- Sanctions under criminal and regulatory offence law

National room for manoeuvre is restricted by EU legislation. For example, emission limits for vehicles are set by the EU as part of the TSI Noise, which, however, only applies to new registrations and does not set any requirements for existing vehicles. Emission limit values for infrastructures and immission limit values are not regulated by EU law; the Member States have room for manoeuvre here, taking into account the general EU requirements. In Germany,

immission control is regulated by the *Bundes-Immissionsschutzgesetz* (BImSchG / Federal Immission Control Act), whereby Section 41 and, on the basis of Section 43 (1), the *16th Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes* (16. BImSchV / 16th Federal Immission Control Ordinance) are of particular importance for the railway. The use of financial subsidies and noise-related track access charges are also partly subject to European legal requirements. EU initiatives by the Federal Government to amend EU legal requirements are in turn part of the national political spectrum of action (see section 2.4 of the report for more details).

3 Procedures for the individual areas of the railway system

3.1 Overview

Chapter 3 of the report discusses the need for action and the possible measures and instruments for noise reduction in the individual areas of the railway system. After the cross-sectional topics of infrastructure and traction units, the types of transport are addressed: regional passenger rail, local passenger rail and regional freight rail, and finally the stabling facilities, especially for regional passenger rail. Each section concludes with specific recommendations.

3.2 Noise reduction in infrastructure

The rolling noise that often dominates railway noise arises at rolling contact, where it is determined by the joint roughness of wheel and rail. Its propagation and radiation depend on many other characteristics of the vehicles and tracks (see chapter 2 of the report). On passenger trains, the wheels of the vehicles are usually very smooth, so that the rolling noise is determined by the rail roughness depending on the condition of the rail. This means that **rail roughness** is increasingly becoming the focus of attention, especially if it is possible to further reduce the wheel roughness of freight wagons. For the propagation and radiation of the rolling noise, the **track decay rate** is particularly important on the track side, which should be as high as possible so that a vibration of the excited rail decays quickly.

There are no regulatory requirements for the acoustic properties of the infrastructure, as the EU is not responsible for this and Germany has not yet formulated such requirements. One exception is the so-called "besonders überwachtes Gleis" (specially monitored track), which is prescribed as part of noise precautions for new buildings or significant changes to railway lines in order to ensure low rail roughness at particularly noisy locations. If measurements are taken for vehicle approval in accordance with TSI Noise, the track sections on which the measurements are taken must comply with the limit values of DIN EN ISO 3095:2014 for rail roughness and track decay rate. It is desirable to comply with these limit values in all inhabited areas.

The technical possibilities for measuring rail roughness and for acoustic grinding are described in section 3.2.2 of the report. It also describes the current state of rail roughness in the German network, which has improved on average, so that the need for additional acoustic grinding operations to achieve the stated objective will be limited. However, there are deviations with higher roughness that become a burden. These often occur as a result of maintenance grinding, among other factors.

The track decay rate is discussed in section 3.2.3 of the report. The intermediate layers installed between the rail and sleeper play an important role here. On lines with a maximum speed of over 160 km/h, elastic intermediate layers must currently be installed, as the track decay rate is generally too low. Innovative, so-called highly damping pads are currently being tested, which can be installed on these lines and whose track decay rate is sufficiently high.

The existing railway regulations do not stipulate any general requirements for rail roughness and track decay rates. The report recommends the introduction of corresponding regulations. **A legal obligation on railway infrastructure companies to ensure that the railway infrastructure is in a proper acoustic condition** can be included either in the *Allgemeines Eisenbahngesetz* (AEG / General Railway Act) or in the Eisenbahn-Bau- und Betriebsordnung (EBO / Railway Construction and Operating Regulations). The obligation can be limited to the

railway network in populated areas – this applies to around 10,000 kilometres of track (see section 3.2.6 of the report for more details).

The acoustically proper condition refers both to maintenance and care as well as the structural design of the infrastructure. With regard to **maintenance and care**, a "smooth rail" must be ensured in particular by regular measurement and acoustic grinding, the latter also as a direct result of maintenance grinding. In addition, irregularities in the running surface such as mud spots or irregular rail welds must be rectified. The infrastructure company reports regularly to the Federal Railway Authority on the acoustic condition of the infrastructure and must rectify any deviations. With regard to the **structural design of the infrastructure**, various design features (such as intermediate layers) must be evaluated acoustically and anchored in the EBO, from which acoustically permissible designs can be derived.

The criteria of DIN EN ISO 3095:2014 regarding rail roughness and track decay rate should serve as the starting point for "proper track condition". Criteria and measures should be continuously developed as part of a permanent **research programme** at the German Centre for Rail Traffic Research (DZSF).

3.3 Noise reduction for traction units

Traction units include the locomotives of goods trains and locomotive-hauled passenger trains on the one hand and electric multiple units (including high-speed trains) and diesel multiple units for passenger transport on the other. With locomotive-hauled trains, the more it is possible to reduce the noise of the carriages, the more the noise of the locomotives becomes apparent. This could be observed, for example, in SGV after the abolition of grey cast iron brake blocks.

The possible **noise reduction measures** are roughly the same for all traction units. Measures can be taken on the compressors, fans, inverters, motors and gearboxes to reduce unit noise, which dominates at standstill or at low speeds (especially when travelling). To reduce rolling, curve and braking noises, which dominate at medium speeds, measures can be taken on the wheels, brake systems and bogies (in particular radial adjustment of the wheels). Aerodynamic noise can already occur at medium speeds due to easily avoidable unfavourable designs; at very high speeds it is unavoidable but can be minimised by measures. These categories of measures are discussed in detail in section 3.3.2 of the report.

The emission limits for traction units have remained virtually unchanged since 2006 despite several revisions or partial revisions of the **TSI Noise**. This contrasts with other EU environmental policy areas in which limit values are usually lowered over time, such as nitrogen oxide or particulate emissions from combustion engines. The experts recommend that the German government work towards lowering the limit values of the TSI Noise as part of an EU initiative. Specific recommendations on the various limit values are given in section 3.3.3 of the report. As a rule, reductions of approx. 5 dB(A) and more should be possible with very little increase in costs.

If the limit values are lowered with transitional periods, the costs for their fulfilment will be very limited in the opinion of the experts, as the TSI Noise only refers to new vehicles and the noise reduction measures mentioned above open up a variety of possibilities for fulfilling the requirements, which have hardly been used so far due to a lack of obligations.

3.4 Noise reduction in long-distance passenger rail transport

The noise emissions of SPFV are a minor problem compared to those of SGV and SPNV. This is due to the relatively lower operating performance of the SPFV (in train kilometres) and the fact that the lines used by the SPFV are mostly already equipped with noise barriers. In addition, the electric multiple-unit trains of the SPFV are generally quieter than those of the SPNV at the same speed.

However, there are still opportunities for noise reduction in the case of regional passenger rail transport, particularly with regard to aerodynamic noise. These noises are partly generated by the roof superstructures and pantographs of high-speed trains, where they are no longer shielded by noise barriers of the usual height. In addition to the locomotives (see section 3.3 above), the passenger coaches should also be addressed in the case of locomotive-hauled passenger trains, as locomotive-hauled passenger trains are generally louder than electric multiple units.

As with traction units, the report recommends an EU initiative by the German government to work towards lowering the corresponding limit values of the TSI Noise. Specific recommendations on the lower limit values to be aimed for are given in section 3.4.3 of the report.

3.5 Noise reduction in local rail passenger transport

Alongside rail freight transport, regional rail transport is one of the main causes of rail traffic noise. This is because regional rail transport dominates in terms of train numbers on considerable parts of the German rail network; this applies particularly in the metropolitan regions, but also in rural areas. These routes are often located very close to residents, as regional rail transport is intended to connect people (which is why the night-time stabling of regional rail transport trains discussed in section 3.7 often takes place very close to inhabited areas). Comparative analyses show that the trains of regional passenger rail services are louder than those of regional passenger rail services (at comparable speeds). In surveys conducted as part of the most recent noise action plan, more than half of the participating municipalities considered themselves to be highly or extremely highly affected by the noise of regional rail transport. In the case of projects to reactivate lines, local residents express their concerns about future noise pollution.

Possible measures to reduce the noise emissions of traction units in regional rail transport correspond to those described for traction units in general (section 3.3 above and in the expert report). Some of these measures can also be applied to regional rail passenger coaches. The door warning noise should also be addressed. Here, the European safety regulations permit an ambient volume that is significantly below the alternative, constant volume of 70 dB(A) in quiet environments.

The need for action in regional rail transport has already led to the Federal Association of Regional Railway Authorities (BSN) proposing specific **noise emission reductions compared to the TSI Noise limit values in** the latest edition of its 2023 vehicle recommendations. They relate to the passing, starting and braking noises of the various vehicles, as well as their stationary noises during operation (e.g. at railway stations), and apply to both new vehicles and used vehicles in new transport contracts, although different values are proposed. See section 3.5.2 of the report.

The experts recommend that the recommendations of the BSN should be adhered to in future for new transport contracts. In addition, transport contracts should require the door warning

noise to be adapted to the environment and the noise during night-time parking should also be reduced (see section 3.7).

The experts therefore consider **the ordering policy of the federal states and public transport authorities to** be the central political instrument for achieving noise reductions in regional rail transport. This is the obvious and indeed the only lever for achieving tangible success within a reasonable period of time, while the parallel path of influencing the EU to adapt the TSI Noise is politically lengthy and uncertain and can only have an impact on new vehicles. An ordering policy that effectively reduces noise must be organised. It cannot be left to the individual authorities responsible for regional rail transport, as their task is to provide transport, not to reduce noise, and as individual tenders or orders for transport contracts do not provide the industry with enough time and opportunity to develop and offer low-noise new vehicles or noise-reducing measures for used vehicles at low cost due to their small size and the limited time until delivery of the vehicles.

The basic prerequisite for rapid noise reduction in regional rail transport is therefore for **the state governments to take responsibility** and set appropriate targets for their public transport authorities. So far, the federal states cannot be blamed in this respect because the issue is new, as rail traffic noise was largely equated with noise from grey cast iron-braked freight wagons until the end of 2021.

It is also urgently recommended that the countries **coordinate** with each other in order to give the industry a standardised and sufficient impetus. This requires a reliable form of organisation. Coordination with the federal government is necessary in any case. Specifically, the report therefore proposes a federal-state agenda for the reduction of rail traffic noise in regional rail transport, which – following preliminary discussions with the industry and other stakeholders – begins with a declaration by the states that low-noise vehicles will be required in all new transport contracts after a transitional period of five years. At the same time, in addition to and independently of the actual regionalisation funds, the Regionalisation Act should provide for a sum of money to be paid to those public transport authorities that subsequently comply with the declaration (for ten years, starting after the transition period). The assessment of this amount of money can be organised in a special way in order to further strengthen the incentive to adhere to the announcement.

The legal possibilities and limits for such a coordinated approach by the federal and state governments are discussed in section 3.5.4 of the report. The possibilities and limits of the applicability of the Regionalisation Act for noise reduction objectives are discussed here. The question also arises as to whether the EU could regard such a coordinated approach at national level as circumventing its responsibility for setting emission limits. The planned coordinated national approach should be clarified with the EU in advance. From the experts' point of view, it seems likely that it will be accepted by the EU in the form outlined.

3.6 Noise reduction in rail freight transport

Even after the abolition of grey cast iron brake blocks, freight wagons are still one of the main causes of rail traffic noise. The report reviewed existing studies on the noise-reducing effects of the following possible measures: Modification of braking systems, wheel slide protection to prevent flat spots and crumbling on the wheels, wheel damper, noise aprons, acoustically optimised bogies, avoidance of noise sources on the wagon superstructures. In many cases, there is still a lack of reliable knowledge about the potential for noise reduction.

Wheel damper are a relevant option for existing freight wagons. They promise a reduction in rolling noise in a straight line of around 2.5 dB(A) (with a range of 1 to 4 dB(A)) and a reduction

in curve noise of up to 10 dB(A). However, the costs are not insignificant, with acquisition costs of around 9,000 euros and additional running costs (increased maintenance costs) of around 250 euros per year for a four-axle freight wagon.

It is questionable whether the SGV sector should be burdened with such a task in the coming years. Only recently, the sector made a decisive contribution to noise reduction by converting from grey cast iron to composite brake blocks. In the near future, the sector will be challenged again with the conversion from screw couplings to digital automatic couplings (DAK). The DAK with its subsequent innovations (automatic brake testing, ep-brake, etc.) is central to the future viability of rail freight transport and thus also to the intended transport turnaround.

There are additional noise reduction options for new cars. A **combination of disc brakes and wheels with a straight wheel web** promises to reduce rolling noise in a straight line by 3 dB(A) thanks to very smooth wheels and an acoustically favorable wheel design (which is only possible with disc brakes). If **wheel-slide protection system** is added, tread defects such as flat spots become rarer. If **innovative bogies** are also added, the rolling noise in a straight line is reduced by a further 1 dB(A) due to their primary suspension, and the curve noise is reduced by up to 10 dB(A) due to radially adjusting wheels. In a straight line, this results in a total reduction of 5 dB(A) over the measures mentioned, if an average of 1 dB(A) is assumed for the reduction of flat spots. Added to this are the effects of the infrastructure measures mentioned in section 3.2.

From an economic point of view, however, there **is currently a problem with the disc brakes**, the core element of this package of measures. Companies that have been using them for a long time and with high mileages are experiencing so-called crumbling on the wheels, a tread defect that can significantly increase the maintenance costs of the wheels (premature replacement necessary) and thus the running costs of using disc brakes. However, the experts consider this to be a solvable problem during the introductory phase of this braking system, which is still new for the SGV. One promising solution is the use of wheel-slide protection system, which improves the braking behaviour of the freight wagons, thus preventing running surface defects and was included in the package of measures for this reason in particular.

The package of measures is primarily aimed **at new combined transport wagons** (container wagons and pocket wagons). These have very high annual mileages of over 150,000 km and often run as block trains in fairly stable sets on the major corridors, even at night. The long-term impact potential of successive noise reduction in this segment is considerable, as the stock of these wagons amounts to approx. 25 % of all freight wagons and is responsible for approx. 50 % of the total wagon mileage (in wagon kilometres) due to the high mileage.

Once the problem of crumbling has been solved, the fundamental advantage of disc brakes in terms of running costs (reduced wheel maintenance costs) will become apparent again. With very high mileages of over 150,000 km, this economic advantage far outweighs the significantly higher acquisition costs of disc brakes compared to clasp brakes, including the costs of the wheel-slide protection system. The wheels with a straight wheel web are cheaper than conventional wheels anyway. The innovative bogies also make economic sense due to the benefits in terms of running costs (in this case, energy savings thanks to the radially adjustable wheels) given the high mileage. The entire package of measures is therefore **profitable** for the wagons of combined transport in the long term (negative costs).

However, it can be assumed that, in addition to this view based on individual costs, implementation and system costs are also incurred, for example in the areas of maintenance and servicing (changeover, training, storage and provision of spare parts, etc.). The report therefore recommends a **funding policy** for equipping an initial quantity of new wagons as well as

accompanying innovation funding to help the new technology achieve a breakthrough. The EU should also participate in this.

However, this will only become relevant in the (foreseeable) future when the problem of crumbling disc brakes has been reliably solved and innovative bogies are ready for the market. Neither is the case today. The research and development required for this should be supported, in parallel with the simultaneous research and development for the DAK and its subsequent innovations, so that **the "modern, low-noise freight wagon of the future",** which combines all these components, will be available on the market **in around 5 years' time**.

A long-term **noise-dependent track access charge system** (which could also take the form of state noise-dependent track access charge bonuses or similar) is essential for this type of noise reduction policy. This is because new vehicles will only gradually arrive in the field and will remain in the minority for a long time. If they were scattered around, they would have no noise-reducing effect for neighbouring residents for decades to come. For this reason, "low-noise goods trains" consisting of 100% low-noise freight wagons must be granted a long-term track access charge advantage so that the relatively few low-noise wagons are combined to form low-noise goods trains and remain together. In addition, the track access charge advantage should not be granted everywhere, but only on selected, contiguous, noise-polluted routes (initially only the Rhine corridor, then other routes of the "Quieter Routes") in order to incentivise low-noise goods trains to be used primarily there. Many of the disadvantages discussed with regard to the previous noise-dependent track access charge system used for the conversion from grey cast iron to composite brake blocks do not arise with a long-term system based on block trains.

The European Directive 2012/34/EU, which is fundamental for the railway sector, provides for a European implementing regulation for the possible design of noise-based track access charge systems, which was adopted in 2015 but repealed in January 2024. Section 3.6.4 of the report discusses in a broader legal context whether the regulatory gap that has now arisen can be filled by national legislation or whether a new EU implementing regulation must first be adopted. The experts recommend that the German government at least clarify the matter with the EU in advance and possibly go further and take the initiative to create a new implementing regulation that enables the proposed noise-based track access charge system, and estimate the chances of success to be high.

3.7 Noise reduction for parking facilities

A stabling facility is a track system for stabling trains, especially at night. In the case of regional rail transport, stabling is sometimes scattered on individual tracks close to the respective operating location the next morning. However, there are also larger stabling sidings on which several trains are parked.

Some stabling facilities are located in residential areas and are hotspots for rail noise. This is because many vehicles continue to be supplied with electrical power at night, with the result that various units such as cooling and heating systems or air conditioning units remain switched on and emit noise accordingly.

A number of **measures can be taken on the vehicles** to minimise noise in parking facilities. These can be divided into **technical-mechanical** measures on the one hand, which include sound-optimised components, encapsulation, silencers and the dimensioning and positioning of units, and **technical-functional** measures on the other, which use hardware and software to enable automated control of units with the aim of demand-optimised, low-noise operation. In addition, **operational measures at the parking facilities** are possible, such as noise-optimised parking and operating processes, maintenance and low-noise design of the infrastructure and

compressed air systems and a feedback and complaints system to identify deficits. If noise barriers are used, they must be very high, as many noise-emitting units are mounted on the roofs of the vehicles. This would be expensive and can also be disruptive. Parking bays are also an expensive solution.

The current **legal situation** with regard to noise from parking facilities is problematic: depending on the classification of noise generation, these are partly subject to traffic-related and partly to facility-related immission control, whereby the distinction is difficult and the relevant legal requirements therefore vary. This also raises demarcation issues. There are also currently no emission limits for vehicles during parking. These will only be introduced with the upcoming revision of the TSI noise in 2028.

The report recommends extending traffic-related immission control to all aspects of parking. As part of traffic-related immission control, **immission limit values** should be set for night-time parking. After a transitional period, they are to apply to all parking facilities, both new ones and those already in use. Compliance with the limit values is to be determined by calculation by extending Schall 03 – which already regulates compliance with immission limit values for the construction of new railway lines – for the stabling process and including noise-reducing measures for stabling.

Parking facilities – like the infrastructure in general – must be kept in a proper condition. Macrophone tests at the parking facilities must be minimised. On the basis of the extended Schall 03, it must be determined for each parking facility which vehicles may be parked in this parking facility and under what conditions. Further aspects of the proposed concept are mentioned in section 3.7.5 of the report. As part of the federal-state agenda for regional rail transport (see section 3.5 above), from a certain point in time only vehicles that are also low-noise when parked should be ordered. The transitional period until the immission protection for stabling facilities comes into effect should be chosen so that a sufficient number of low-noise vehicles are already available.

4 Comprehensive immission control for new and existing lines

Statutory noise immission protection for residents living near railway infrastructure currently only exists for the new construction or significant modification of railway lines (so-called noise precautions, Section 41 (1) BImSchG). In contrast, there are no general immission control regulations for existing railway lines. In the case of existing lines that were subject to planning approval at an earlier date, limit values that would no longer be permissible under current legislation may have had to be complied with. In these cases and also in the event of changes to the operating programme of a route (i.e. the number, type and timing of the trains running on it), there is currently no routine procedure for reviewing and adapting the noise protection measures.

Noise protection on existing railway lines has so far only been granted as noise remediation as a voluntary federal benefit under budgetary law, whereby the type of noise protection measures largely corresponds to those of noise prevention, but the trigger values for voluntary noise remediation are in some cases considerably higher than the immission limit values for new construction and significant changes to railway lines. In addition, only some of the cases that meet the trigger values are actually remediated each year, depending on the respective financial framework of the noise remediation programme. The routes to be refurbished are mainly selected according to the degree of noise pollution.

The report recommends extending the legal entitlement to noise immission control to existing routes in the long term and thus also establishing a procedure for the gradual review and adaptation of noise protection measures for routes that have already been plan-approved. Chapter 4 of the report describes and recommends how this can be legally implemented. The immission limit values should be identical for existing and new lines, as they are justified by health protection. However, the restrictions of Section 41 (1) of the Federal Immission Control Act (BImSchG) should remain valid, according to which the health-damaging traffic noise must be avoidable at all according to the state of the art and the costs of the protective measure must not be disproportionate to the intended protective purpose. As before, the protective measures are to be assessed mathematically in accordance with Schall 03 (Annex to the 16th BImSchV), which thus becomes the central instrument for implementing immission control. Section 4.2.1 of the report therefore discusses in detail the possibilities of including noise-reducing measures in Schall 03, because as a basic prerequisite for the expansion of immission control, it is necessary to include as many relevant measures as possible – in particular those recommended in this report – in Schall 03. A normative prioritisation of the measures should also be carried out as a concretisation of the principle of proportionality, which is based on criteria such as effectiveness, costs, range of the immission reduction achieved, proportionality of the impacts and other relevant aspects of the measures under consideration. This suggests that, as a result, **measures at the source** will be prioritised above all.

However, the extension of immission control to existing railway lines can only take place **after a longer transitional** period of around ten years and then only **gradually** over the course of a further decade. The actual impossibility of such an approach with regard to the necessary technical resources and materials and the required personnel, the financial impossibility with regard to the foreseeable costs, in particular in view of an as yet inadequate catalogue of noisy railway lines, and the fact that it would not be possible to implement such an approach without a transitional phase, speak against an immediate nationwide uniform extension of the railway-specific immission control legislation to all railway lines without a transitional phase. in view of the still inadequate catalogue of noise-reducing measures in Schall 03, the legal impossibility

with regard to conflicting basic legal principles such as protection of the status quo and legitimate expectations, legal certainty and proportionality, as well as the administrative impossibility with regard to the administrative procedures to be carried out and their foreseeable duration and the necessary administrative capacity.

The successive, staggered implementation of immission control on the individual stretches of road must be carried out in a standardised manner according to a noise pollution-oriented prioritisation, similar to the current noise abatement. Due to the long periods of time involved**, noise abatement** should **be continued for the time being and** only **replaced by immission control on a route-by-route basis** in accordance with the staggered implementation schedule.

Please refer to section 4.2 of the report for details of the organisational, administrative procedural and substantive legal approach to the comprehensive extension of immission control legislation to railways.

5 Summary and central pillars of noise abatement policy

The aim of the report is to develop a **comprehensive noise protection concept for rail transport**. This is summarised in chapter 5 of the report. To this end, section 5.1 first summarises the recommended instruments and measures for vehicles and infrastructure as well as for the expansion of immission control, similar to this summary.

The **timeframe for the recommended measures** has a start-up phase of around five years, which is primarily characterised by political preparations and some initial implementation of measures. The continuation of noise abatement is therefore an important element of the recommendations, so that noticeable noise reductions can be achieved at some hotspots even before then. The measures relating to infrastructure, regional rail transport vehicles and new combined transport freight wagons will gradually take effect. Finally, the extension of immission control to stabling facilities and successively also to existing lines – with a corresponding replacement of noise remediation – will have an impact. See section 5.2.1 with Figure 42 of the report.

The **effects on the number of people affected** are calculated in chapter 6 of the report (for the main federal railway lines). They depend on the expected traffic development and the degree of implementation of the recommended measures (medium / high / complete), as explained methodically in the following section. **Without the measures recommended here** (only if noise abatement is continued), the number of people affected will increase due to traffic development; with a traffic trend forecast of 8.8 % from 2.45 million to 2.7 million people, with traffic development in line with the objectives of the traffic turnaround even by 30.7 % to 3.2 million people. Such a scenario would not be compatible with the idea of the transport transition. **With an average degree of implementation of** the measures recommended here (and the continuation of noise abatement in parallel), the number of people affected would decrease by 8.2 % in the trend forecast. However, if the traffic turnaround is realised, the number of people affected would still increase by 9.7 %. With a **high degree of implementation,** the number of people affected will fall in any case, by 44.3 % or 16.3 %. If the measures are **implemented in full**, it will fall by 72.8 % or 63.4 %.

The calculation of the **economic benefit of the measures recommended here** (without taking noise abatement into account) is based on a traffic development that lies between the trend forecast and the traffic turnaround forecast. This results in an annual economic benefit of EUR 250 / 600 / 1,200 million if the measures are implemented to a medium / high / full extent. This leads to present values of 5 / 12 / 24 billion euros if a (rather high) social discount rate of 5 % is assumed.

On the other hand, **the costs of the measures are manageable**. Less than 41 million euros are calculated annually for the costs of keeping the railroad infrastructure in a proper acoustic condition. The low-noise freight wagons generate negative economic costs, as they are even economically profitable. The costs of low-noise traction units for passenger and freight transport will vary greatly depending on the type of measures that have to be taken by the industry to comply with the limit values (or, in the case of regional rail transport, the values required for orders). If adjustments in the area of fans are sufficient, the cost increases will be minimal. The most expensive adjustments are in the area of gearbox design. In cases where fundamental redesigns are necessary to reduce noise, price increases of up to 4 % have been estimated for new vehicles, which can amount to 160,000 euros or 7,500 euros per year over the lifetime of a locomotive.

The following **central pillars of the recommended noise abatement policy** can be summarised cross-sectionally:

- **Standardised approach and closure of regulatory gaps:** The emission limit values for vehicles (TSI Noise) should be accompanied by specifications for the proper acoustic condition of the infrastructure. Legally regulated traffic-related immission protection should apply not only to the construction or significant modification of railway lines, but also to stabling facilities – within a standardised legal framework – and in the long term also to existing lines. This long-term goal also serves as a continuous incentive for politicians to push for accompanying instruments. In all cases, immission control is implemented in mathematical form, i.e. without on-site measurements in accordance with Schall 03.
- **Federal-state agenda for noise reduction in regional rail transport:** Assuming that both the federal states and the federal government have a common interest in noise reduction for the population and in broad acceptance of the railways, they should coordinate and agree on a coordinated and organised approach to noise reduction in regional rail transport vehicles that keeps the costs of implementation low. The people in the federal states will also benefit from all other measures implemented by the federal government, such as infrastructure and rail freight transport.
- **Noise-dependent track access charge system as a flexible instrument for the internalisation of noise externalities:** Environmental levies are a classic instrument of environmental policy (e.g. CO_2 levy on fuels; additional CO_2 component in the lorry toll and consideration of EURO emission standards), which should also be used in the rail sector. A long-term noise-dependent track access charge system is indispensable if noise reduction in rail freight transport is to be realised cost-effectively only for *new* freight wagons, which then need to be used in a targeted way, however. It can be used flexibly, e.g. to include locomotives at a later date.
- **EU initiative:** The European requirements for railway noise are of central importance. Here, the federal government must work continuously and in a targeted manner towards continuous reductions in the limit values of the TSI Noise. The coordinated approach of the federal states to the ordering of regional rail transport vehicles with the involvement of the federal government must be agreed with the EU, as must the intended use of the noise-dependent track access charge system. The EU should participate in the direct subsidisation of low-noise freight wagons.

6 Assessment of the noise reduction potential of the recommended measures

The following steps are used to estimate the noise reduction potential:

1. Traffic forecast of operating performance (in train kilometres) in SPFV, SPNV and SGV
2. Forecast of the effects and implementation of noise-reducing measures
3. Result immission forecast: change in the number of people exposed

In the transport forecasts, a distinction is made between a trend forecast for 2030 (extrapolation of the trends of recent years) and a transport transition forecast in which the transport transition targets are assumed to have been achieved. Although these targets were also formulated for 2030, they deviate so strongly from the 2030 trend forecast that they actually describe a state that will not be achieved until well after 2030. The implementation of many of the instruments and measures recommended in this report will also only become noticeable after 2030. A qualitative distinction is therefore made between different degrees of implementation for the immission forecasts:

- Medium degree of realisation: medium effort and / or duration
- High degree of realisation: strong effort and / or longer duration
- Full implementation: very long duration; upper limit

The case of no implementation serves as a basis for comparison. The assumed effects of the measures are presented in detail in section 6.2 of the report for the various degrees of implementation. For example, a reduction of 2 dB(A) is assumed for the "smooth rail" infrastructure in the case of full implementation, but this is only assumed for 30 % of the lines in the case of medium implementation. With regard to the track decay rate, a reduction of 3 dB(A) is assumed, but this is also only applied in the full implementation for lines above 160 km/h maximum speed.

The immission forecasts are based on the noise mapping of the Federal Railway Authority, whose exposure figures are interpolated to 1 dB(A) level classes. The noise-reducing measures then result in shifts in the exposure figures to lower level classes. Further deductions are made from the noise exposure figures to take into account the noise abatement measures that only have a localised effect.

In a first, generalised approach, an "overall immission forecast" is drawn up, for which all structural parameters must be levelled (uniform growth rate for all three traffic types, uniform effects of the measures, etc.). The main results of this simple calculation were presented in the previous section.

In a second, differentiated approach ("forecast in sub-areas"), the analysis is limited to those municipalities where it can be plausibly argued that the same conditions prevail within the municipality (so-called "one-way municipalities"). It is then possible to take into account some important structural parameters of these municipalities (e.g. shares of traffic types, different relevance of the various measures depending on the traffic type) and to carry out differentiated analyses of the effects of the measures with the help of a tool.

It can be seen that the overall results of both forecasts, the overall immission forecast and the forecast in sub-areas, are in strong agreement.