Development of a concept for quieter rail transport in Germany

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Introduction

The authors (as project consortium) developed a concept for quieter rail transport in a research project entitled '*Verkehrswende und Konzept für einen leisen Schienenverkehr bis 2030*' (Transport transition and concept for quieter rail transport by 2030) on behalf of the Umweltbundesamt (German Environment Agency), *funding reference 3721 54 102 0*. This article presents extracts from this concept.

Even after the abolition of grey cast iron brake blocks in rail freight transport, rail transport continues to be a relevant source of noise for millions of people in Germany. More than 2.4 million people are exposed to noise above the WHO recommendations [1] based on the weighted day-evening-night level and 4.2 million people based on the night-time level. These figures from the fourth round of noise mapping [2, p. 127f.] are based on the 2021 annual timetable and apply to the main federal railway lines (in densely populated regions and on railway lines with over 30,000 train journeys per year). The total number of people affected in Germany is therefore higher. In view of the number of people already exposed to noise and the desired general transport transition, including an increase in rail traffic, reductions in rail traffic noise are necessary for reasons of health and acceptance.

Sources of sound in rail transport

Noise pollution during a train pass-by can occur as a result of two propagation paths. In the case of primary airborne noise, airborne noise emitted by the vehicle or track is transmitted through the air. Secondary airborne noise occurs as a result of structure sound excitation and transmission as well as subsequent sound radiation from vibrating components (e.g. walls). The research project focussed on primary airborne sound.

The dominant sound sources when a train passes by depend on the speed of the train. In the lower speed range (up to approx. 50 km/h) engine noise, in the medium speed range (up to approx. 300 km/h) rolling noise, and at higher speeds aerodynamic noise dominates. The actual proportions depend heavily on the specific vehicles, the driving situation and the infrastructure conditions. The latter has a very large influence on the rolling noise emitted. This depends heavily on the wheel and rail roughness. While the former is primarily related to the braking system of the vehicle, the latter depends on the condition of the rail surface and can be reduced by grinding, for example. To minimise the excitation of rolling noise, both wheel and rail roughness should be as low as possible. Disc brakes are particularly conducive to low wheel roughness, as is common in passenger rail transport. The abolition of grey cast iron brake blocks has already led to a significant reduction in wheel roughness of freight wagons. However, freight wagons are still equipped with block brakes (with K or LL blocks), which brake on the running surface and cause a certain roughening of the wheels.

The track decay rate (TDR) is the relevant parameter with regard to the sound radiation of the rail. The TDR describes how quickly a vibration excitation decays along the length of the rail at a distance from the point of excitation. A high TDR is acoustically favourable, as the vibration of the rail decays 'quickly' after a train passes and therefore emits relatively 'little' sound. With a low TDR, the rail vibrates relatively freely on the sleepers and emits more sound. The TDR is influenced in particular by the rail pads. Hard rail pads (a long time the equipment standard in Germany) ensure a high TDR whereas soft rail pads (common for some time on all tracks with a speed of over 160 km/h) lead to a low TDR. The negative effect of soft rail pads on the pass-by level is estimated to be up to 4 dB [3, p. 7].

Traction units are also a relevant source of noise. Analyses for the noise monitoring stations in Switzerland have shown that locomotives are responsible for the maximum noise level of freight trains in one third of pass-by journeys [4, p. 27].

Differences between market segments and main actors

Rail transport can be divided into rail freight, local rail passenger and long-distance rail passenger transport. In addition to the differences due to the distinct vehicle types and speeds, the various economic and political conditions must also be taken into account. Furthermore, the infrastructure manager can be considered separately, as it has a significant influence on rail roughness and track decay rate and thus on rolling noise.

Policies aiming at noise reduction of **rail freight transport**, are particularly challenging for many reasons. Due to the competition between the various rail transport companies and with trucks, there is a high cost pressure. Due to the distributed maintenance and various contractual constructs of wagon owners, carriers and railway companies as well as the strong mixing of wagons in train formation on a European scale, it is difficult to set incentives right for the different actors, particularly by a single member state.

The **local rail passenger transport** is a relevant source of noise in the metropolitan regions, but also in rural areas on secondary lines. The transport service is provided by various railway transport companies. The financing and tendering of the corresponding transport services is carried out by the public transport authorities of the federal states and therefore with public money. There is competition between the various rail transport companies as part of the tendering process, with different tendering models for vehicle procurement. The tendering market regime can be used as a vehicle for noise reduction policies.

Long-distance rail passenger transport is not directly subsidised in Germany. There are both national and increasingly international connections, but only little competition between different railway companies.

European and national regulations

The acoustic emissions of vehicles are regulated at European Level by the **TSI Noise** [5]. This has been in force since 2006 and defines limit values for various measurement scenarios, including stationary noise, starting noise and pass-by noise. Different values apply depending on the vehicle category. Since 2006, there have only been minor and barely noticeable reductions. The limit values are only valid for new vehicles, meaning that a reduction in the emission limit values will only in the long term have a broad impact. The European emission regulations for vehicles restrict the national scope for action, as vehicles that fulfil the European regulations must be granted access to the national railway infrastructure. This means that Germany cannot issue regulations that go beyond the TSI Noise, for example, which would exclude vehicles that are 'too loud' (e.g. freight wagons or long-distance trains).

With regard to **infrastructure**, there is greater national room for regulations. Basic technical characteristics for a standardised European railway infrastructure are regulated at European level. However, this leaves a lot of room for member states to set detailed technical specifications for the railway infrastructure manager with the aim of reducing noise emissions.

The **immission control** and its limit values are also regulated at national level. For railway traffic (parking facilities are not included here), a distinction is made between noise prevention and noise remediation. **Noise prevention** applies in the case of new construction or a significant change to a track. In this case, residents are legally entitled to immission control in accordance with the *Bundes-Immissionsschutzgesetz* (BImSchG; Federal Immission Control Act, [6]) in combination with the *Sechzehnte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes* (16. BImSchV; 16th Federal Immission Control Ordinance, [7]). Immission control has been in force, with modified limit values and calculation methods, since 1974, so that new high-speed railway lines, among others, are already equipped with noise mitigation measures (according to the immission control at that time). **Noise remediation** is an additional voluntary measure by the federal government to reduce immissions along existing tracks, which is not based on a legal entitlement of the residents. For both cases, noise prevention and noise remediation, the calculation of the immissions is based on Annex 2 of the 16th BImSchV, the so-called **Schall 03**, which contains assumptions for the noise emissions of corresponding vehicles, infrastructures and reductions depending on the noise mitigation measures.

If noise mitigation measures are not depicted in Schall 03, they do have an effect in reality, but there is no legally acknowledged effect on the immission forecast and any further measures. The existing noise mitigation measures in Germany are primarily applied to the infrastructure, in particular in the form of noise barriers and, in some cases, rail web dampers, rail web absorbers and the so-called 'specially monitored track' as well as passive measures like the installation of soundproof windows.

Recommendations – Infrastructure

With regard to the infrastructure, the authors recommend a reduction in **rail roughness** to the level of the limit curve for pass-by measurements of DIN EN ISO 3095:2014 [8]. This 'smooth rail' should be achieved by increased acoustic rail grinding (especially directly after maintenance grinding) and monitored by regular checks (e.g. every 12 months). In this way, a reduction in vibration excitation in the wheel-rail contact can be achieved. The requirement for rail roughness should be regulated on 'lines adjacent to populated areas' (approx. 10,000 km) by a newly introduced legal obligation for the railway infrastructure company, for example in the *Eisenbahn-Bau- und Betriebsordnung* (EBO; Railway Construction and Operating Regulations, [9]). The 'smooth rail' and its acoustic effect should also be included in Schall 03 so that it can be taken into account in immissions forecasts.

One advantage of this approach is that the responsibility lies solely with the infrastructure company. In addition, the measure can be implemented relatively quickly, even if more grinding vehicles are required in the future. Current acoustic grinding methods work at very low speeds. This is not an issue if acoustic grinding is applied in conjunction with maintenance grinding (which is also slow, beside high speed grinding). Independent acoustic grinding currently requires a temporary track closure. In the coming years, however, it is foreseeable that grinding processes with higher speeds will also be able to fulfil the corresponding requirements. Figure 1 shows an acoustic grinding vehicle, which is currently used for grinding of the specially monitored track.

Figure 1: Grinding vehicle GWM 550, Photo: customized (tailored) ‚Schweer-Bau-GWM-550-Schienenschleifmaschine', Reinhold Möller, https://commons.wikimedia.org/wiki/File:Schweer-Bau-GWM-550-Schienenschleifmaschine-P8115004.jpg, CC BY-SA 4.0.

For the **track decay rate**, the authors recommend the use of so-called highly damping rail pads (also called optimized rail pads) instead of the soft rail pads, see for example [3]. The condition is that the highly-damping rail pads successfully pass the current operational tests. Possible additional costs of the rail pads or of slightly higher wear on the superstructure are expected to be insignificant and, if occurring, should be weighed up against the acoustic benefits in an economic assessment. This also requires inclusion in Schall 03, or an acoustic negative assessment of the soft rail pads. The aim is for the TDR to also fulfil the limit curve of DIN EN ISO 3095:2014 in inhabited areas. A regulation is also possible in the EBO (Railway Construction and Operating Regulations).

Recommendations – Reduction of TSI Noise values

The authors recommend lowering the TSI Noise limits for traction units and passenger coaches. Sufficient noise reduction options exist for the corresponding vehicles. However, due to the highly competitive situation, particularly in rail freight transport and long-distance rail passenger transport, there is no economic incentive to procure quieter vehicles. Since national regulations for these types of transport are not possible, the German government should work as part of an EU initiative towards a reduction of the emission limits for vehicles in the TSI Noise. The reductions differ according to vehicle and noise category. The authors are convinced that significant reductions (in the range of 5 to 15 dB) for stationary noise, moderate reductions (4 to 9 dB) for starting noise and slight reductions (2 to 5 dB) for passing noise are technically and economically feasible.

Due to the ongoing process for the revision of the TSI Noise for 2028/29, it is questionable whether the topic can be placed on the European agenda by then. Furthermore, the majority of member states would have to be convinced of the need to reduce emissions. Nevertheless, Germany should pursue this path in order to achieve a reduction in one of the future revisions. The authors are convinced that this is necessary, as the long service life of vehicles means that vehicles registered in the 2030/40s will emit the same noise in the 2060/70s as vehicles already emitted in the 1990s – despite ongoing technical developments and emission reductions in many environmental areas. Only a lowering of the TSI noise limits can ensure a sustainable and widespread reduction of vehicle emissions.

Figure 2: Lok 2000, Photo: Markus Eigenheer, https://www.flickr.com/photos/78631472@N03/44493818020/, CC BY-SA 2.0.

One example for the technical feasibility is the Lok 2000, developed at the end of the 1980s, shown in Figure 2, which is significantly quieter than today's locomotives. The proposed reductions cover both rail freight transport (locomotives) and long-distance and local passenger rail transport (locomotives, coaches, multiple units).

Recommendations – Local rail passenger transport

In local rail passenger transport, quiet vehicles should be used even before a revision of the TSI Noise regulations. The responsibility for this lies with the federal states, which can require vehicles with lower emission levels when awarding transport contracts through their public transport authorities. To encourage the industry to develop cost-effective quiet vehicles, the federal states should act in a coordinated manner and communicate this future requirement to manufacturers at an early stage. In consultation with the federal government, and in exchange with the EU to avoid conflicts with European law, a federal-state agenda for reducing rail noise in local rail passenger transport should be developed. In addition to the existing federal regionalisation funds for financing local rail passenger transport, an annual financing should also be provided to support the use of low-noise vehicles.

If these are also reflected in the Schall 03 calculations, this would create an incentive for the federal government to support this approach, as it may substitute infrastructure-related noise mitigation measures as part of the immission control. A particular feature of this approach is that it should apply not only to new vehicles but also to used vehicles within the framework of new transport contracts. This would allow for a moderate reduction in emissions from regional rail transport even in the medium term.

Recommendations – Rail freight transport

Even after the abolition of grey cast iron brake blocks, freight transport remains a main source of rail traffic noise. In view of the general cost pressure, the planned introduction of the Digital Automatic Coupling and the European agreement regarding brake blocks, the authors currently consider a reduction in the emission limits for freight wagons in the TSI Noise to be unrealistic.

However, with wheel sound absorbers, disc brakes (in combination with wheels with a straight wheel web and wheel slide protection system), as well as acoustically favourable bogies, there are some measures on freight wagons that can be applied to reduce emissions. One possibility for noise reduction is seen in direct funding for the financing of noise-reducing measures (by the EU and/or member states). Programmes to promote innovation are also possible. In addition, a noise-dependent track access charge system (or track bonus system) should be realised in the future. This should aim to ensure that trains are made up entirely out of quiet freight wagons, as the acoustic effect on a train pass-by is significantly reduced if some loud freight wagons are part of the train.

This approach is aimed in particular at block trains in combined transport. These are often used on the same destinations, meaning that maintenance for additional/other components can be implemented more easily. More importantly, wagons and trains in combined transport have a very high mileage, implying that they have an important role in noise emissions and that they are particularly responsive to noise-dependent track access charges or bonuses.

Conclusion

The concept developed for reducing rail traffic noise contains various components. Legal national regulation is possible and recommended for the infrastructure and its acoustic properties. Specifically, the rail roughness in populated areas should be reduced to the level of DIN EN ISO 3095:2014, the same is planned for the track decay rate. In order to achieve a sustainable reduction in vehicle emissions, the Germany government should work at European level for a reduction in the noise limits of the TSI Noise. A faster realisation of quieter vehicles seems possible for local rail passenger transport. As the public transport authorities procure transport services, they should and can demand quieter vehicles. The procurement of cost-effective, quiet vehicles should be achieved through a coordinated approach by the federal and state governments in consultation with the EU. For rail freight transport, a funding policy and the introduction of noise-dependent track access charges are recommended.

Measures on the infrastructure (rail roughness, track decay rate) and on the vehicles (different forms of quieter vehicles) should be part of the Schall 03. This is the only way to have an effect on immission control reports and to provide a monetary incentive to implement the measures at source.

Further topics were addressed as part of the research project. For example, noise reduction in parking facilities of local rail passenger trains, which could be realised through technical measures on the vehicles, operational measures on the parking facility and technical measures on the infrastructure. In addition, parking processes should be included in the railway-specific immission control (currently the legal situation shows uncertainty as to whether the immission control or the TA Lärm [10] is to be applied). Furthermore, the authors investigated the option to introduce a legal entitlement of residents for noise prevention for all tracks (not only in case of new construction or a significant change). This would have quite substantial legal and practical consequences. It could only be rolled out in a considerable period of time, but, if tailored well, can have beneficial incentive effects for all parties involved.

In order to estimate the effect of the increase in rail traffic and the introduction of noise reduction measures, traffic and immission forecasts were made based on the fourth round of the noise mapping [2]. The immission forecasts show that without the introduction of further measures, there will be a significant increase in rail traffic noise pollution due to the increase in traffic. Implementation of the recommended measures (depending on the scope) can offset this effect or even lead to a reduction in the number of people affected.

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