Remaining Research Topics for Railway Noise Control

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Summary
Since the early nineties of the 20th century, railway noise has been the subject of many, mostly collaborative, research projects. As a key result, in five years from now, freight trains in Europe will be some 10 dB(A) quieter than before. As freight trains have represented the obvious priority of both researchers and policy makers, the new decade calls for a new focus and possibly for new topics to be investigated. These emerge around a better understanding of relevant phenomena, a better understanding of the impacts that are typical for railway noise (and vibration), and a better communication with affected residents and the politicians representing them.

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1. Introduction

In the early nineties of the 20th century, the joint European railways commissioned leading research institutes (TNO, the Netherlands, Keele University UK, and ISVR, UK) to study train wheel rail interaction. The underlying hypothesis was that rolling noise was the major generating mechanism of railway noise, and that this was caused by wheel and rail irregularities, with wheel and rail interacting. A key result of this research work was a validated numerical model (TWINS) [1], which allowed predicting the efficiency of a wide range of interventions. The TWINS model supported a series of research projects, some of them co-financed by either the European Commission or national states, such as the EU framework projects, the French-German collaboration projects and many others. As a direct result, in less than 5 years from now, freight trains will be substantially quieter – typically 10 dB - than before. As a more indirect effect, the Technical Specification for the Interoperability, TSI NOI, specifies type test limits for pass by and stand-still of new trains to be admitted to European tracks. Compared to other modes of transport, including road traffic, air traffic and inland shipping, the railways achieved a major reduction. In addition to this achievement, thousands of kilometers of sound barriers have been installed and hundreds of thousands or dwellings have received sound proof windows. In Switzerland alone, over the last 15 years, the national railway company SBB has spent some 1.2 billion euro for railway noise control, bringing about 85% of the population below the legal threshold of noise exposure, with the remaining 15% provided with sound proof windows. In The Netherlands alone, until 2011, 500 km of noise barriers have been installed along the network, representing some 8% of the total network length. Such figures allow for the statement, that railway noise is sufficiently controlled as it is, and therefore, there would be no need for further research.

2. Shared responsibility and cost efficiency

Even if this statement were justified, a drastic improvement of cost efficiency would be required, considering the fact that either public funding is at stake (noise barriers) or the cost of noise control affects the operational cost of freight and passenger transport. Above all, noise control should not affect the competitive position of railway transport, being the most sustainable and safe, and therefore preferred mode of transport.

One of the success factors of rail freight noise control is that the retrofitting of freight wagons focuses on the rolling stock, whereas conventional noise control (barriers) is considered to be the responsibility of the infrastructure manager. Compliance with the TSI NOI appears to be sufficient even for rolling stock operated in highly sensitive areas. The system approach, often referred to as a necessity, is not always fully explored, when the noise performance of the rolling stock is considered to be an inevitable fact. Solutions to control traction noise and engine noise have not yet been explored completely. If noise dependent track access charges could be applied to other areas than freight retrofitting, an incentive for quieter vehicles in sensitive areas could be achieved. On top of rail condition monitoring, wheel condition monitoring and subsequent maintenance would constitute a substantial improvement in some cases. This is an element of the system approach, where the vehicle owner should accept the responsibility.

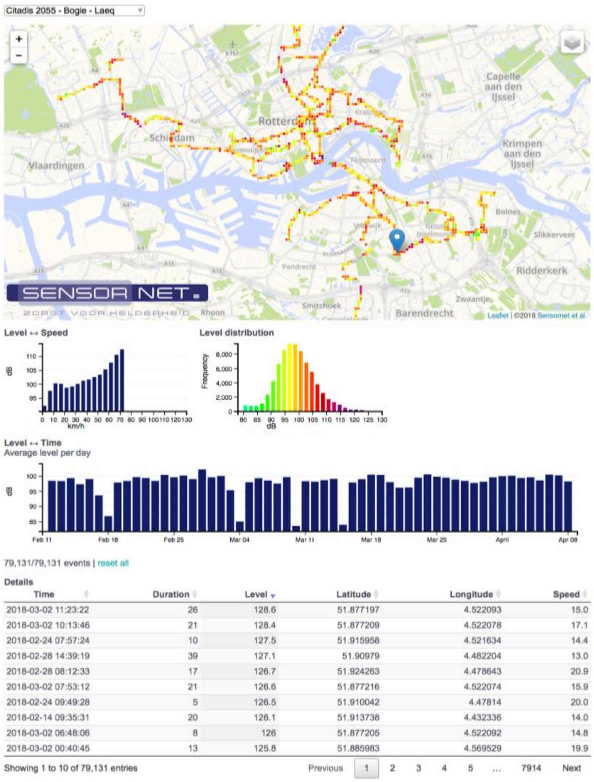

Figure 1. An example of a dashboard for monitoring of the infrastructure of the light rail network of Rotterdam.

3. Perception

Exposure response relationships for railway noise have been applied for many years, both in legal frameworks such as the Environmental Noise Directive and in impact assessments. The 2002 Position Paper [2] and the underlying meta-analysis still represent an important reference, but its general validity has often been questioned. This happened to situations with high speed traffic, with dense freight traffic, with very light traffic intensity, with combined noise and vibration exposure, with traffic at night, and several others. Recent insights from WHO [3] result in higher impacts at similar exposure, and consecutive unrealistic recommendations for limit values. In Germany the difference in impact between road and rail noise was recently omitted and there is a call for new indicators for night time noise.

All this is based on field studies and laboratory studies from many different researchers. The communality is that there is a rise in research efforts wherever there is a peak in community response and political attention. Field studies usually attempt to relate exposure levels (outside, at the façade) to self reported annoyance of residents inside the house, with unknown façade insulation, with unknown window setting, with unknown time spent at home as opposed to at work, to name just a few of the many uncertain but influential conditions. There is a need for more detailed and more standardized methods in field studies, certainly with respect to night time noise and its various effects like sleep quality, sleep cycle disturbance, awakenings, motility; some of these resulting in health effects.

For daytime noise, the long term average noise level may not be sufficiently adequate, certainly not when the residents are exposed to types of noise that are perceived as particularly disturbing. Tonal noise from curve squeal or brake screech, and impulsive noise from joints and turnouts, are likely to be perceived as particularly annoying. They may give rise to complaints, that usually land at the infra manager's desk. Ways to assess the appraisal of such noises and to derive suitable indicators with sufficient reproducibility, for example based on the sound scape approach, have only just been identified as a subject for further research.

4. Acoustic comfort

Previously, the research program was set up mainly by the former railway companies, currently operators. Today, the manufacturers are in the lead. Their research questions refer to the contractual interface between the supplier/designer of rolling stock and the client purchasing or operating it. Acoustic comfort in the train is a key factor for passenger satisfaction. From passenger surveys it was found that comfort in general is considered far more important than e.g. punctuality or even safety. When setting up the specification for a new rolling stock to be commissioned, there is hardly anything referring to comfort in general and acoustic comfort in particular. That is due to the fact that a common language and common indicators are still to be identified and defined. In the design phase, auralisation and visualization may help to involve future passengers in the assessment of good quality acoustic comfort. This is a fairly new field of work; similar to the perception issues treated in the previous section, a sound scape approach is a promising method to be further developed.

5. Ground vibration and ground borne noise

Ground vibration and ground borne noise have seen a rapid increase of interest from the general public and from decision makers. Whether ground borne noise (audible noise originating from a vibration transmitted through the ground) or vibration (perceived as vibration, transmitted through the ground) is at stake, depends on the frequencies generated at the source, and on the dynamic properties of the ground and of the building around the observer. Reliable prediction tools are required in planning situations, but these require a comprehensive collection of data of the track construction, joints and switches, track conditions, the soil under the track and between track and receiver, and of the response of the building. Moreover, such models require a substantial amount of modeling for every single building and sometimes even for every single floor. In addition to that, effective mitigation options are hardly available and if so, only at very significant costs. Rail vibration is a field where, even after the RIVAS project [4], still a lot of work has to be done: in standardization, in data collection, in developing methods and in inventing and testing solutions.

6. Specific extraordinary conditions

For normal geometry, with residential dwellings at a distance of at least 50 m from the track and average rail traffic during day, evening and night, the current national noise limits can only be achieved with significant mitigation measures, i.e. barriers and/or sound proof windows. The WHO may come up with guidelines that recommend possibly lower limits than the common ones. In extraordinary situations, for instance where houses are close to the track (in the order of 10 to 25 meters), it will not be feasible to maintain a normal traffic and comply with stricter limits. The freight lines through the Rhine Valley in Germany are a good example. Even with the freight fleet retrofitted, extraordinary measures, such as complete enclosures, tunnels or roofs would be required.

Could this kind of problems be solved by further research. The 10 dB reduction from retrofitting the freight fleet is an exceptional efficiency. And even there, essential practical problems, e.g. in extreme winter conditions, have been reported. It is highly unlikely that any future research will deliver a result of similar size. Any further improvement of wheel rail interaction might mitigate rolling noise by some 3 – 5 dB to the maximum.

7. Aerodynamic noise

Aerodynamic noise may become more important when more barriers are installed along a track. The noise sources at low height will generally be screened sufficiently, but the pantograph (and other sources on the roof of the train) may be noted distinctively due to its position overlooking the barrier’s diffraction edge.

For aerodynamic noise, the modelling is still under development. Reliable prediction models exist but are still very laborious.

8. Rolling noise

Nevertheless, there is still work to do at the wheel rail interface. The causes and generation of wheel roughness and other wheel defects are generally well understood. The methodology to prevent or mitigate these is still in a testing phase. Cost are an important issue to overcome. With respect to rail defects, including rail roughness, the generation is not completely understood yet. There are various theories, but none of these has been acknowledged as the key phenomenon. Grinding is a solution but the effects of the various grinding techniques and the growing of roughness are not understood sufficiently.

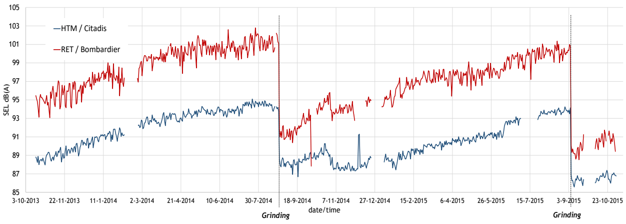

Figure 2. An example of the increase of noise level due to rail roughness and the effects of grinding for two types of light rail vehicles.

Moreover grinding comes at a cost and the technique and frequency are relevant. For curve squeal, lubrication techniques are applied but are costly and may have negative effects to adhesion and signalling. Turnouts and switches are sources of impulsive noise that are hard to avoid or mitigate.

The current design of tracks and bogies builds on two centuries of practical experience. The dynamics of this integrated system could be optimized from a noise point of view. Currently promising attempts are being made with rail pads having optimised stiffness (stiff in one frequency range, soft in another).

Related to this issue is the application of rail dampers (also known as tuned rail absorbers). Although generally well understood, the efficiency of these devices is subject to high expectations in many cases where the result may be somewhat disappointing. Clearly, with stiff rail pads, there is a high amount of track decay rate and rail dampers will not add a lot to that. With soft rail pads however the efficiency could be noticeable.

Optimising and understanding the full range of track and bogie dynamics is a way of small steps ahead, but many different small steps may result in a substantial progress.

9. Fantasy at work

The two centuries of experience mentioned before have produced a transport system with unique safety and a high amount of standardization. It could improve in many aspects but maintaining – or even improving – the current safety level is always top priority. Introducing something new and different in a world of high standardization may have adverse commercial effects. Some freedom of mind is necessary to come to brilliant ideas. In a new research program, researched should also be given the opportunity of complete freedom of design, to have imagination and fantasy do their work.

10. Conclusion

In the past, associations of railway parties like train operators and infrastructure manager have worked with academia and technical consultant to control and reduce noise from rail traffic. Currently many people are well protected from excessive noise. Vehicle manufacturers have joint this field and are prepared to contribute. Together they intend to contribute to a modal shift to rail. Different research platforms and forums are discussing the topics. Most of these topics have been discussed in the present paper. Although a lot has been achieved, there is still a scope for further and partially different and new work.

Acknowledgement

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References

[1] D.J. Thompson, Wheel–rail noise generation, part I: introduction and interaction model, Journal of Sound and Vibration 161 (1993),387–400.

[2] Position Paper on Dose Response Relationships between Transportation Noise and Annoyance, ISBN 92-894-3894-0

[3] WHO Environmental Noise Guidelines for the European Region, limited draft February 2018

[4] http://rivas-project.eu/fileadmin/documents/Publications/newsletter_rivas-pages_final.pdf