Notes on Numerical Fluid Mechanics
and Multidisciplinary Design 126

Jens C.O. Nielsen · David Anderson
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Noise and Vibration Mitigation for Rail Transportation Systems

Proceedings of the 11th International Workshop on Railway Noise, Uddevalla, Sweden, 9–13 September 2013

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Notes on Numerical Fluid Mechanics and Multidisciplinary Design

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Editors
Jens C.O. Nielsen
Department of Applied Mechanics/CHARMEC
Chalmers University of Technology
Göteborg, Sweden

David Anderson
Acoustic Studio Pty Ltd.
Stanmore New South Wales
Australia

Pierre-Etienne Gautier
SYSTRA
Paris, France

Masanobu Iida
Railway Technical Research Institute
Environmental Engineering Division
Tokyo, Japan

James T. Nelson
Wilson, Ihrig and Associates
Emeryville, USA

David Thompson
University of Southampton Inst. Sound and Vibration
Southampton
United Kingdom

Thorsten Tielkes
Deutsche Bahn AG
Munich
Germany

David A. Towers
Harris Miller Miller and Hanson Inc.
Burlington
USA

Paul de Vos
DHV BV, Amersfoort
The Netherlands

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Preface

This volume contains the peer reviewed contributions to the 11th International Workshop on Railway Noise (IWRN11), which took place in Uddevalla, Sweden, on September 9–13, 2013. The workshop was organised by the Competence Centre in Railway Mechanics (CHARMEC) and the Departments of Applied Mechanics and Applied Acoustics at Chalmers University of Technology in Gothenburg, Sweden. It was supported by Bombardier Transportation, voestalpine Schienen, Lucchini and Chalmers / CHARMEC.

The workshop was attended by 160 delegates from 19 countries around the world: Sweden (33 delegates), Germany (18), United Kingdom (17), France (12), The Netherlands (11), China (8), Australia (7), Austria (7), Belgium (7), Czech Republic (7), Denmark (7), Switzerland (6), Japan (5), United States (4), Norway (3), South Korea (3), Spain (3), Finland (1) and Hong Kong (1).

Railway traffic is, in comparison with other modes of transportation, safe and environmentally friendly and is generally described as the most sustainable mode for regional and international transports. According to the White Paper on Transport, issued by the European Commission in 2011, one of the key goals by 2050 is a 50 % shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport. This will contribute to a 60 % reduction in carbon emissions by the middle of the century. To promote the shift from road to rail, the environmental impact induced by the railway in terms of noise and vibration needs to be further reduced.

Since the first IWRN in 1976, held in Derby (UK) with some 35 delegates, the workshop series has been established as a regular event that every three years brings together the leading researchers and engineers in all fields related to railway noise and vibration. The workshops have to a great extent contributed to the understanding and solution of many problems in railway noise and vibration, building a scientific foundation for reducing the environmental impact by air-borne, ground-borne and structure-borne noise and vibration.

Following the tradition from previous workshops, the scientific programme of IWRN11 was held as a single-session event (no parallel sessions) over three and a half days. The programme contained 55 oral presentations and 36 poster presentations, the latter including a three-minute oral presentation to introduce each poster. The present volume contains the peer reviewed papers from 84 of these presentations, including 2 state-of-the papers on ground-borne vibration due to railway traffic and on railway noise generated by high-speed trains. IWRN11 covered 9 different topics of railway noise and vibration: 1. Prospects, legal regulation and perception, 2. Wheel and rail noise, 3. Prediction, measurements and monitoring, 4. Ground-borne vibration, 5. Squeal noise and structure-borne noise, 6. Aerodynamic noise generated by high-speed trains, 7. Resilient track forms, 8. Grinding, corrugation and roughness, and 9. Interior noise and sound barriers.

There is no formal organisation behind the IWRN but rather an informal, committed International Committee. It supports the chairman during the preparation process with the experience and expertise of its members. Assistance is given to formulate the scientific programme by reviewing the submitted abstracts, to act as session chairmen, and to act as peer review group and editors of the IWRN proceedings published in this volume.

The International Committee is grateful to Anders Frid, Wolfgang Kropp, Roger Lundén, Astrid Pieringer and Peter Torstensson of the local committee for their great commitment and care in organising the workshop. Special thanks to Pernilla Appelgren Johansson, Christian Johansson and Sara Nielsen for their work related to the administration, communication and graphic design of material for the Workshop, and to the staff of Bohusgården Hotel & Conference Centre.

The editors of this volume are grateful to Professor Wolfgang Schröder as the general editor of the "Notes on Numerical Fluid Mechanics and Multidisciplinary Design" and also to the staff of the Springer Verlag (in particular Dr Leontina Di Cecco) for the opportunity to publish the proceedings of the IWRN11 workshop in this series. Note that previous workshop proceedings have also been published in this series (IWRN9 in volume 99 and IWRN10 in volume 118).

We hope that this volume will be used as a "state-of-the-art" reference by scientists and engineers involved in solving noise and vibration problems related to railway traffic.

June 2014

Jens C.O. Nielsen
David Anderson
Pierre-Etienne Gautier
Masanobu Iida
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Thorsten Tielkes
David A. Towers
Paul de Vos

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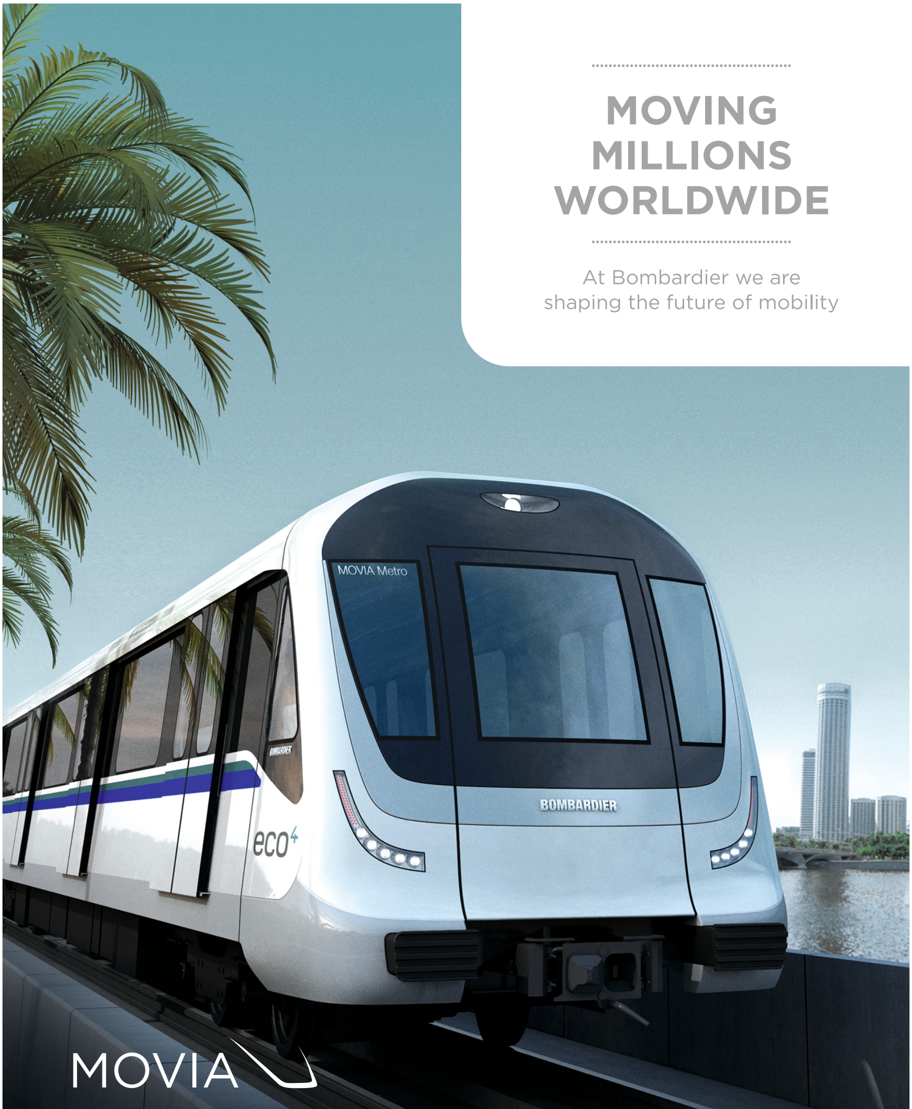

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Railway Noise Control in Europe: Current Status

J. Oertli

Swiss Federal Railways, Infrastructure
Mittelstrasse 43, 3000 Bern, Switzerland
jakob.oertli@sbb.ch

Summary. Railways are a sustainable means of transport. Nonetheless, railways do have an influence on the environment. The most important effect is noise, especially the noise emitted from freight trains.

European Union policy supports noise reduction and has addressed the issue in interoperability directives and corresponding technical specifications. The Environmental Noise Directive (END) requires member states to submit noise maps and action plans. The EU is mostly responsible for noise creation aspects, while member states may additionally enact specific legislation for noise reception. Numerous studies have considered the economics of railway noise control, comparing the costs and benefits of different noise control possibilities. Based on these studies, the railways have adopted the following noise control strategy: 1) Reduce the noise of all new freight vehicles by introducing TSI limit values. 2) Promote the retrofitting of existing freight vehicles with composite brake blocks. 3) Build noise barriers and install insulated windows. 4) Pursue further solutions in special cases.

Noise differentiated track access charges (NDTAC) have been proposed as the main incentive for retrofitting the rolling stock by the EU and several European countries such as Switzerland.

Although the railways have made considerable progress in railway noise reduction, several problematic trends may be observed: 1) There is a tendency towards protecting capital instead of people, for example by introducing compensation for home owners based on property values. 2) Whole system optimizations are rare and infrastructure measures may counteract noise reduction efforts. 3) There are exaggerated expectations from certain new technologies. 4) Often the overall picture is not considered, such as the trade off between noise control and the modal split between road and rail. 5) Simplifications may lead to wrong conclusions, for example the noise reduction potential of a given measure often depends on local conditions and generalizations are not possible.

1 Introduction

Railways are a sustainable and climate friendly means of transport. Nonetheless, railways have an influence on the environment, the main effect being noise, especially

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the noise emitted from freight trains. This paper summarizes the main railway noise activities in Europe in terms of policy, economics, technical possibilities as well as the strategy of the railways to deal with noise issues. It concludes with some problematic trends.

The author is chairman of the UIC (International Union of Railways) Network Noise and Vibration. This article is based on the information gained through the work and contacts of this network.

2 European Policy and Incentives

European sustainability policies include promoting the railways. A recent activity in this field is the Greening Transport Package (COM/2007/0551). To enable this, railway noise concerns must be addressed. European noise legislation includes the Environmental Noise Directive (END, 2002/49/EC) which requires noise maps and actions plans, the recast of the first railway package (Directive 2012/34/EU), adopted in November 2012, which foresees an optional introduction of noise-differentiated track access charges, and the Technical Specifications for Interoperability (TSI) which define noise creation values for certain types of rolling stock. The TSI set maximum levels of noise produced by new (conventional) railway vehicles. In addition reducing the existing noise limits for new wagons and locomotives is on the agenda and a revised TSI Noise is planned for the end of 2013 or the beginning of 2014.

European research framework programs include numerous railway noise projects. A financing for silent freight rolling stock may be possible through the Connecting Europe Facility (COM/2011/665/3) with a substantial budget earmarked for transport projects. It allows the EU to co-fund retrofitting of existing freight wagons with silent brake blocks with a maximum of 20 % of the eligible costs. As of this writing (May 2013), the proposal was in discussion between the Parliament and the Council.

In a recent (April 2013) road map [1], the EU Commission describes different options for promoting the retrofitting of freight wagons with silent composite brake blocks. These include a baseline scenario where no action is planned, increased financial support for retrofitting, NDTAC, mandatory application of TSI Noise limits to existing railway wagons (which would lead to a de facto ban of cast iron brake blocks), introduction of noise limits along the Trans European railway network. An assessment of the impact of these scenarios is planned until the mid 2014.

3 National Legislation and Incentives

National legislation differs throughout Europe. Many countries have reception limits for new and significantly altered lines, however only Switzerland, Italy and Norway have limits for existing lines. Usually limit values apply to the façade of buildings but in some cases (e.g. Norway) they apply to indoor areas. In The Netherlands, Germany and Switzerland noise differentiated track access charges are in effect. Germany, France and Austria spend considerable amounts on existing lines, even though noise abatement is not stipulated by the legislation. Finally, there is a Swiss plan to ban cast iron brake blocks by 2020.

Most European countries have national incentives and policies promoting the implementation of retrofitting the rolling stock with silent brake blocks. The most prominent examples are Switzerland, where all Swiss rolling stock is in the process of being retrofitted with composite brake blocks. This programme is financed by the government, which in turn receives the funds mostly from the road sector. Switzerland has also introduced noise differentiated track access charges (see chapter 6). The Netherlands are also very active in promoting retrofitting. Some of the activities include the launching of numerous studies and pilot projects to test composite brake blocks and the introduction of noise differentiated track access charging. Also, in Germany, noise differentiated track access charges have come into effect. Additionally Germany has strongly supported the development of LL-brake blocks (see chapter 5). A summary of national initiatives and legislation is given in the 2010 UIC state of the art report on railway noise [2].

4 Economics of Railway Noise Control

Numerous studies (e.g. the STAIRRS project [3]) have considered the economics of railway noise control, comparing the costs and benefits of different noise control possibilities and combinations thereof. In general, noise barriers, especially high ones have a poor cost-benefit ratio, while retrofitting the freight fleet has a beneficial cost-benefit ratio. To date network wide cost benefit studies for other measures (e.g. rail dampers, rail grinding) however are lacking.

5 Noise Control Strategy of the Railways

The railways have adopted the following noise control strategy: 1) Reduce the noise of all new freight vehicles by introducing and adopting TSI limit values. 2) Promote the retrofitting of existing freight vehicles with composite brake blocks. 3) Build noise barriers and install insulated windows. 4) Pursue further solutions in special cases. Such further solutions include rail dampers, acoustic rail grinding, solutions for trains parked in depots and stations, solutions against curve squeal, measures on steel bridges, and to improve the noise situation in railway freight yards. The current situation in terms of retrofitting and noise barriers is as follows:

Retrofitting: Railway rolling noise is caused by rough wheels on rough rails, significant noise reduction can be achieved by replacing cast-iron brake blocks with composite brake blocks. Two types of composite brake blocks are available: 1) The K-blocks are homologated however require adapting the wheel set due to the different braking characteristics. This makes retrofitting a fairly expensive option. 2) The LL brake block has similar braking characteristics to the cast iron brake block. This makes retrofitting less expensive than with K-blocks. The EuropeTrain project tested the LL brake block on 200’000 km throughout Europe. Homologation of this brake block was approved

mid 2013. Production of these brake blocks must be started before large scale retrofitting can be undertaken. It must be noted that retrofitted freight wagons both with K- and with LL-blocks incur higher life cycle costs due to a greater wheel wear. This increase in life cycle costs has, however, not been adequately quantified to date.
Noise barriers: A large amount of noise barrier construction has taken place in the past years. Until 2007 a UIC survey [4] indicated that at least 1000 km of noise barriers were built along railway lines in Europe. A total of € 150 – 200 Million are spent every year in Europe on noise barriers to mitigate railway noise.

6 Noise Differentiated Track Access Charges (NDTAC)

Noise differentiated track access charges (NDTAC) have been proposed as the main incentive for retrofitting the rolling stock by the EU Commission and several European countries such as Switzerland, The Netherlands, and Germany. The recast of the first railway package (Directive 2012/34/EU), adopted in November 2012, foresees an optional introduction of noise-differentiated track access charges. To date there has been little effect from this incentive; however the effect may increase with larger participation. Major risks of this incentive are: 1) the wagon owners who must undertake the investment are often different from the operators who stand to gain from the reduced track access charges and 2) to date it is unclear if the proposed levels of NDTAC will cover the additional life cycle costs incurred by retrofitting.

7 Problematic Trends

Although the railways have made considerable progress in railway noise reduction, several problematic trends may be observed:

1) There is a beginning tendency by government agencies towards protecting capital instead of people. For example Van Praag and Ferrer-i-Carbonell [5] propose noise compensations based on income, where richer people are entitled to higher compensation in absolute money terms. Another example is Switzerland, where legislation is being discussed to compensate home owners based on the value of their property. The compensations would have to be paid for by the railway infrastructure manager and the exact modalities are still being developed. These ideas would serve as an incentive to undertake more noise control in areas with high incomes or high property values, rather than where noise levels are highest or the largest number of people is affected.
2) Whole system optimizations are rare. For example noise barriers are often preferred over retrofitting the rolling stock, even though in most cases a mixture of both measures would provide for the best cost-benefit ratio. Also, an optimization of all construction parameters is rare. This may lead to the introduction of measures against vibrations, which, might lead to more noise being generated. Another example it the introduction of soft rail pads for the purpose of infrastructure maintenance without considering the effects on noise. Optimization

of entire systems would probably lead to lower overall costs and higher benefits for all involved parties.

3) There are exaggerated expectations from many new technologies. Often these are tested in unclear circumstances resulting in high effectiveness. The railways are then under pressure from authorities to implement these technologies, even though they do not perform well under real circumstances or may have security or maintenance problems. Examples, where this has happened include rail dampers and low height noise barriers close to the track.
4) The effects on the split between traffic modes are not sufficiently considered. Since the railways are a sustainable means of transport, it is important that the costs for noise control measures do not change the modal split of transport in favor of other modes (in the process also increasing the noise emissions of other modes). This risk must be considered when discussing mitigation options, since the railways operate in a very competitive market. It is therefore in the interest of society as a whole to finance railway noise control from outside of the railway system.
5) Simplifications may lead to wrong conclusions. For example the effectiveness of a certain noise mitigation method often depends on local conditions and generalizations are not possible. Results from one community or project usually cannot be extrapolated to entire networks.
6) Failure to use proper experimental designs: When testing new technologies, the inherent variability of noise measurements, local conditions etc. is often not considered, so that the tests do not have an appropriate number of replicates and no correct statistical analyses are undertaken. Nonetheless, the results from these tests are used to make policy decisions which may involve many millions of Euros.

8 Outlook

In sum the railways have become quieter and will continue to do so. Retrofitting freight rolling stock with composite brake blocks is the most effective measure and efforts must and will continue in this regard. The main incentive for retrofitting will be noise differentiated track access charging. However, more noise barriers will be built while additional measures such as rail dampers or acoustic rail grinding will prove useful in hot spots. When considering noise mitigation options, it will become increasingly important to look at entire systems, be it on the level of track construction or the traffic policy level.

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Novel Legislation for Railway Lines and Motorways in The Netherlands

P.H. de Vos

Royal Haskoning DHV bv,
Postbus 1132, NL3800BC Amersfoort,
The Netherlands
paul.de.vos@rhrhv.com

Summary. In 2012 The Netherlands Parliament agreed to a revision of the national Noise Legislation, including the introduction of Noise Production Ceilings for national motorways and railways [1]. Ceiling values are derived from the current calculated noise levels at a large number of reference points along the road or track. Ceiling values are open to the general public. The infrastructure manager is responsible that the ceiling values are respected at all times, i.e. including due to traffic growth. Within the ceiling values he then has an autonomous right to implement mitigation measures or even to apply changes to the track, without further legal procedure. To residents the new system offers more certainty with respect to their future noise situation. To the infrastructure manager it offers flexibility to tune the railway's capacity to the transport demand without lengthy legal procedures. The system suffers from low credibility both with the general public and with politicians. To a certain extent this is due to the complexity of the first implementation of the system. The low credibility leads to a strong wish to check calculated levels by means of measurements. The next few years, after the first implementation problems have been solved, will decide if and how measurements can solve the credibility problem.

1 Introduction

On the occasion of the TSI-Noise for conventional speed and the TSI-High Speed coming into force, an attempt has been made to limit the noise production of railway vehicles, at least for vehicles entering on the market and operating in international traffic. In due time, the existing freight fleet will be either retrofitted or phased out, either through effective incentives or through the inclusion of limits for existing wagons into the TSI-Noise. Thus, substantial progress has been made since these options were first suggested, e.g. in the 6th IWRN in Voss, Norway. It is however not only the noisy part of the fleet, but also the increasing traffic intensity on the main railway lines that causes public concern and reactions. Since 1987, the national policy

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in The Netherlands and several other countries has been to impose a standstill on the noise exposure from existing railway lines. In fact, the text of the original Dutch regulation suggests, that any change of the railway line causing a significant increase of the noise exposure would require the infrastructure manager to take mitigation measures ensuring this stand still (at least in as far as the exposure levels would exceed the preferred limit values). The shortcoming was that a possible increase of noise exposure levels would only be identified on the occasion of a spatial planning procedure, i.e. in the course of a planned extension of the railway under concern. The mere increase of traffic on the line, i.e. without planning procedure, would indeed result in an increase of the noise exposure, but the responsibility to mitigate the effect of this increase was never assigned and moreover the increase would remain unobserved. In the decade to follow this legislation coming into force there was a significant increase of rail traffic, both freight and passenger, on many lines. Residents would apply for noise protection, even in court, but their applications were never successful. This affected the credibility of the state as a protector of its residents' rights and well being. It also caused severe opposition against railway transport in general from residents and their political representatives.

The situation as described above is more or less identical in several other European countries with strict noise legislation. These countries would encounter the same credibility problem and might be tempted to solve it in the same way as The Netherlands intended.

18 years later, a proposed revision of the Noise Control Act was adopted in Dutch Parliament, implementing Noise Production Ceilings for main motorways (i.e. roads managed by the state road authority) and main railways (i.e. managed by the national infrastructure manager ProRail). The current paper introduces the new legislation and illustrates the possible benefits and drawbacks of the ceilings.

2 Noise Production Ceilings

2.1 How the System Works

The ceiling is derived from the calculated noise level at a large number of virtual reference points along the track, representing the traffic and track situation as it was assessed during the three years preceding the year when the ceiling was set. A margin of 1.5 dB is added to this calculated noise level in order to arrive at the ceiling value. Once the ceiling has been officially set, it is the responsibility of the rail infrastructure manager that it is never exceeded.

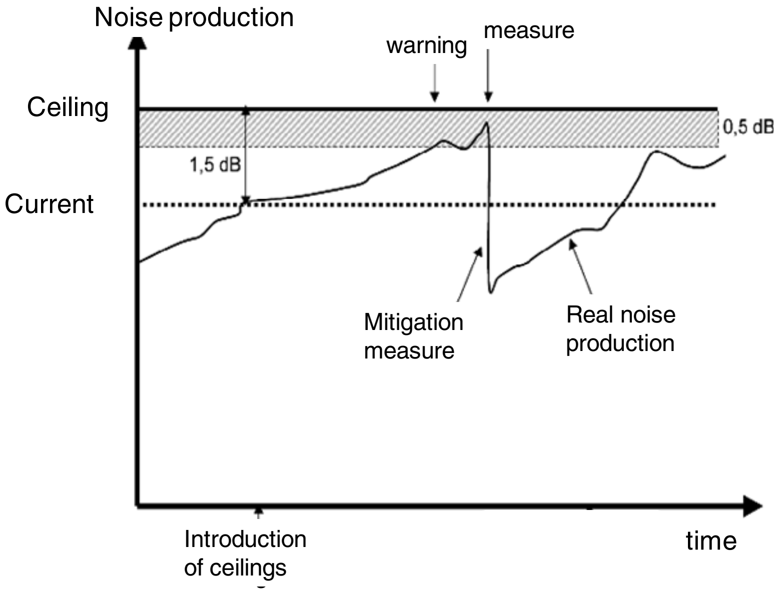

Fig. 1. How the system works

He shall publish a report, on an annual basis, to demonstrate that he has achieved this. He can select the most economic way to reduce noise, but to stay within the ceiling the mitigation would have to be at the source: rail grinding or rail dampers would be an obvious option. Quieter trains would be another option. Fewer trains would also work, but in view of the key objective of the infra manager, i.e. to provide sufficient track capacity to efficiently cope with the demand, this would be the least preferable option.

For all these options, the mitigation can take place without any legal procedure. The demonstration to have stayed within the limit will follow from the annual report. For these options the noise exposure will not increase as long as in every reference point the calculated level remains within the limits. This is different for the application of noise barriers. In the case of a noise barrier being installed, the infrastructure manager will have to demonstrate that the barrier efficiency is sufficient at nearby dwellings or else apply for a revision of the ceilings. Such a revision is also required in the case of an increase at a site without sensitive dwellings. A revision can only be granted by a Ministerial approval.

The advantages of this system are manifold: the residents are ensured that the situation at the start of the system will not be worsened, with the exception of the 1.5 dB margin which allows a 40% traffic growth. Local developers are certain of the noise created by the railway line and can plan their noise mitigation measures when setting up new living areas. And the infrastructure manager can increase the traffic and even make small changes to the line without having to produce a time consuming and costly acoustic survey with potential risk of rejection in court, at least as long as he demonstrates that levels have stayed within the ceilings.

2.2 Points of Discussion

When the new legislation was proposed, the main issues raised were the ceiling level at introduction of the system and the margin necessary to allow a reasonable traffic growth without mitigation. A comprehensive impact assessment study was carried out, in assignment of the former Dutch Ministry of Housing, Spatial Planning and Environment, to assess consequences of various scenarios, both for road and rail [2]. In case of an expected future excess of the ceiling value, the system should allow sufficient time for planning and preparation of mitigation measures that would avoid that excess. This case was simulated using various economic growth scenarios, with the corresponding transport developments for road and rail. For freight it was assumed that 80% of the fleet would have been retrofitted in the study's reference year 2020. In addition, the number of sites exceeding the ceilings should be limited such that the system would be manageable for the infrastructure manager, both in terms of work load and in terms of costs. At the same time, the effects on the overall noise exposure of residents along main roads and tracks would have to be limited and certainly better than under the current legislation.

The study concluded that the yearly fluctuations in traffic intensity are far more significant for rail than for road, which led to the conclusion that the starting point for the ceiling for railway noise would have to be based on a three years average. A range of scenarios was used for different values of the margin, viz. 0.5 dB, 1.0 dB, 1.5 dB, 2.0 dB and 2.5 dB. It was found, that the 1.5 dB represents that optimum both in terms of economic and managerial criteria and in terms of annoyance and health effects. The overall, quantitative conclusion is summarized in the following Table 1.

Table 1. Overall results of the impact assessment study comparing four different options for the margin to be included in the ceiling values

	Working margin			
	0.5 dB	1.0 dB	1.5 dB	2.0 dB
Feasibility Implementation	-	-	-	-
Feasibility Amount	-	-	+	+
Cost	-	-	+	+
Annoyance/Health	+	+	+	+

2.3 Details of the System

A grid of approximately 60,000 virtual reference points, each 100 m apart and 50 m from either side of the track, at 4 meters above local ground, was defined around the 3,000 km of railway track in The Netherlands. In each point, the calculated noise level in dB L_{den} was averaged over the three years 2006, 2007 and 2008. The resulting value is increased by the working margin of 1.5 dB, allowing some 40% growth of traffic. All the reference points and the corresponding ceiling values are kept in a public register, published under the responsibility of the Minister of Infrastructure and Environment.

The infrastructure manager must report, on an annual basis, the compliance of the actual calculated noise level at each reference point with the ceiling levels. If an excess of the ceiling is expected, the infrastructure manager must take appropriate mitigation measures with a noise reducing effect which he can then include into the calculated level. No legal procedure is required for such measures, unless the selected measure represents a noise barrier. In that case a formal revision of the ceiling must be applied for (the Minister of Transport is responsible to allow such a revision). In the case of such a revision and where noise sensitive dwellings are present, the noise exposure at the façade(s) has to be assessed and compared to legal limits.

What if the noise exposure level already exceeds the maximum legal exposure limit? Then the infrastructure manager will have to assess this exposure level, and offer noise mitigation measures resulting in a reduction of this exposure. Once these measures have been implemented – a substantial state budget is foreseen to achieve that throughout the whole country by 2022 – the ceilings will have to be reduced thus reflecting the situation after implementation.

Ceilings may be revised, i.e. increased or decreased, but any such change will require the Ministerial formal approval. Municipalities may request a decrease of the ceiling enabling them to realize urban development along the track within the legal limits. Such a decrease of the ceiling may be viable by the city erecting a noise barrier along the track, at its own cost, or else paying for alternative mitigation. An increase of the ceiling could be requested by the infrastructure manager, in order to avoid costly measures, for instance at locations without residents.

Finally, an overall reduction of all ceilings could be requested by the Minister of Environment, for instance the case of a technical improvement of the rolling stock that would reduce its noise production.

3 Merits and Drawbacks of the New System

The new system has some clear advantages, compared to the previous legislation:

- Residents are better protected against increasing noise exposure due to traffic growth,
- There is more transparency for the residents,
- If someone intends to develop a plan for sensitive buildings along the track, there would be no more discussions about the future noise exposure, as this would be strictly defined by the situation where the ceiling is entirely used,
- The usual discussions with residents on the validity of traffic predictions can be avoided, thus reducing the risk of legal procedures,
- Some track modifications or track renewals can be carried out much faster, because there is no longer a need for a noise impact assessment as long as the effect remains within the ceiling
- The new legislation is likely to enhance a wider application of rail absorbers and has most probably contributed to set off the retrofitting of freight wagons on Dutch track.

Clearly there are some drawbacks as well:

- The 60,000 ceiling values are calculated using a simplified method. This results in differences between the ceiling values on the one hand and noise levels for other legal procedures or noise mapping on the other. This makes the system difficult to explain to residents and politicians.
- Clearly, the infrastructure managers, both road and rail authority, have gone through a very complex process to collect and process all the data required to set up the register and to implement the regular compliance checks. Errors will keep occurring for a while, sometimes with serious consequences.

The latter drawback has far stretching consequences because relatively minor errors in published values tend to affect the overall credibility of the whole system. Residents have grown to be suspicious of any information supplied by the authorities. The tendency is that both residents and politicians demand that the published ceiling levels be checked by means of sound measurements. Such demands and the proposed projects answering to these demands tend to ignore the facts, that noise levels alongside railways are significantly affected by the track and wheel quality, which may differ from year to year, from location to location and from one train to another. For many years, the long term average noise emitted by a particular rolling stock has been the basis for the legal prediction models, in combination with the average track roughness and damping properties. It would be a step back if this were to be replaced by a preference for measured values, with all the unexplainable variations involved.

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Bearable Railway Noise Limits in Europe

F.B.J. Elbers and E. Verheijen

dBvision, Groenmarktstraat 39, NL-3521 AV Utrecht,
The Netherlands
frank.elbers@dBvision.nl

Summary. The question 'What are bearable limits for environmental railway noise?' is discussed regularly in different forums on a national scale and on a European level. A systematic evaluation of all aspects in what 'bearable' could consist of was always missing. The UIC research Project 'Bearable limits and emission ceilings' [1, 2] has brought UIC in the position to propose for the first time a well-balanced limit for noise reception. This noise reception limit is a trade-off between the disturbing impact of noise for line side residents and realistic possibilities for viable railways. Findings are based on an extensive study that was commissioned by the UIC and carried out by dBvision in the Netherlands.

A bearable value of noise reception limits for the night (L_{night}) is not lower than around 55 dB. More stringent limit values are not effective because:

- For values above 55 dB railway noise is the dominant source for sleep disturbed persons in urban areas near railway lines. For values lower than 55 dB, it is more effective to spend money on measures for road traffic noise. This will generally result in more reduction of the overall sleep disturbance.
- Below 50 dB, results show a large increase of cost. Noise limits up to 55 dB are cost-effective.

Results are based on a 202 km railway line sample Rotterdam – Venlo and extrapolation to the ERTMS corridors. These ERTMS corridors are defined in the European Rail Infrastructure Masterplan as the main freight corridors (see Fig. 1).

1 Developments

Different developments put pressure on noise limits. The four most important developments are:

1. The European Commission put pressure to prevent an increase of noise due to growth of freight rail traffic [3].
2. The World Health Organization (WHO) put pressure on limits for noise. WHO has proposed stringent limits for night-time environmental noise [4].

J.C.O. Nielsen et al. (eds.), *Noise and Vibration Mitigation for Rail Transportation Systems*, Notes on Numerical Fluid Mechanics and Multidisciplinary Design 126, DOI: 10.1007/978-3-662-44832-8_3

3. There is an enormous variation in noise limit values between EU Member States. The limits mainly refer to new lines. In general, a less stringent noise limit applies to upgraded lines and/or existing lines [2, 5].
4. European freight transport by rail is expected to grow by 80 % from 2007 until 2020 [6].

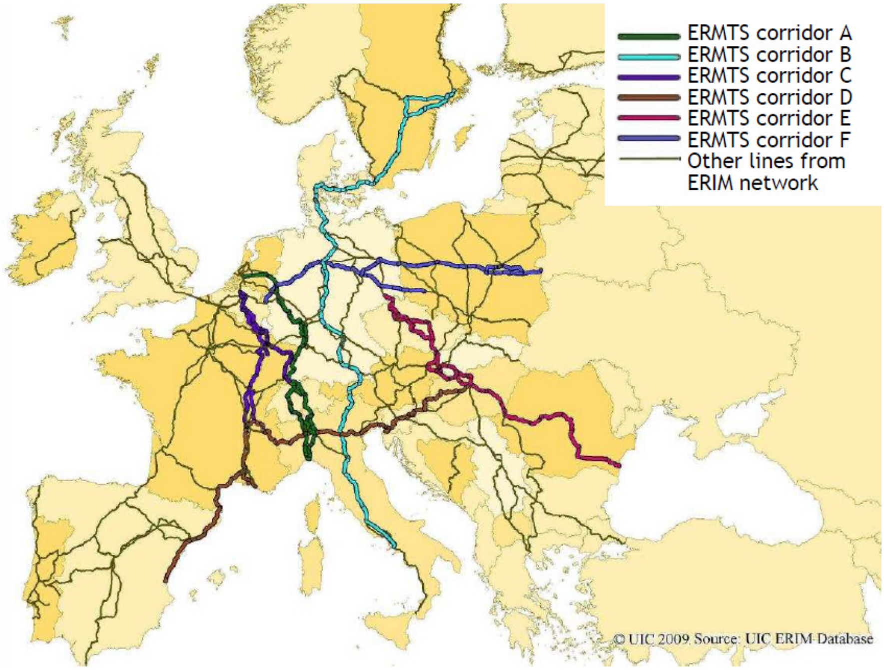

Fig. 1. The UIC ERIM network of international rail corridors. This network is mainly for freight on which a European Rail Infrastructure Masterplan could be built (UIC Atlas 2008 of Infrastructure in the ERIM Network).

The next two paragraphs describe items number 1 and 2 in more detail.

1.1 Railway Freight Noise Policy of the EC

Despite its environmentally friendly image, rail transport encounters substantial public opposition to noise in some European regions. The Commission believes that "if no remedial action is taken, this could lead to restrictions in rail freight traffic along the most important European rail corridors. A possible modal shift from rail to road on these corridors would lead to increasing environmental impacts." [1].