UNION INTERNATIONALE DES CHEMINS DE FER
INTERNATIONALER EISENBAHNVERBAND
INTERNATIONAL UNION OF RAILWAYS

Noise Creation Limits For Railways

Background information

from

UIC SUBCOMMISSION NOISE AND VIBRATION

1. Introduction and Objectives

This paper contains greater detail of the technical background to the UIC report "Noise Creation Limits for Railways: Main Report on the Railway's Position". This technical knowledge has been built up by the collective endeavour of acoustic experts from railways, universities and research institutes over a period of more than 30 years.

The paper considers:

- Issues involved in the measurement of noise
- Noise prediction models
- Noise creation characteristics of existing rolling stock
- Research results and the potential for further noise reduction
- Recommendations for future noise levels

2. Measuring Noise

Before it is possible to discuss appropriate noise creation limits for railway vehicles, it is necessary to address certain questions of principle:

- to what extent should limits reflect normal (ie variable) conditions of operation, rather than performance in controlled circumstances?
- If the latter is selected, how prescriptive should the test conditions be?

An important criticism of the type approval limits for road vehicles in the European Union is that the limit values and the method by which compliance is checked are not representative of normal operating conditions. As a consequence limit values have been reduced several times, but without much noticeable effect on the noise created by road traffic. One reason is that the type approval test is dominated by engine noise, whereas in normal operation noise from the interaction between tyre and road surface is dominant. Another reason is that the gear/engine speed combination which must be maintained during the type approval test is not representative of most of the engine conditions during normal traffic. Not only is it desirable that a similar outcome should be avoided for noise creation from rail vehicles, it is also necessary that type testing of road vehicles is altered to reflect a more realistic context.

Directly linked to this issue of defining type testing conditions is the updating of the ISO 3095 standard for railway noise creation measurement, prEN3095. The key issue is the better reproducibility of measurements. This will require a much tighter specification of the track construction and of the roughness of the railhead of a track used for type testing. An important question which has yet to be resolved is whether such a specification will permit type-testing to be undertaken on operational track in good condition or whether it will require the use of test track facilities.

Wherever in the current document noise levels are stated, the default definition is the Transit Exposure Level (TEL), expressed in dB(A), assessed at a horizontal distance of 25 m from the centre line of the nearest track, at a height between 3.5 and 5 metres above railhead level . This is the microphone position preferred by the committee editing the present report because the majority of measured and historical data is for this position. Measurements are made at 25m by SNCF and DB for all trains and in other countries 25m is preferred for high speed trains.

It is recognised, that however measurements at 7.5 m are technically preferable in some cases as stated in pr. EN 3095. It is assumed that, as a first approximation, the difference in noise level at 25 m and at 7.5 m from the centre of the nearest track is 7 dB(A).

In the past data has been normalised to a reference speed of 100 km/h, which is still preferred by a majority of railway experts. Since many freight vehicles have a maximum operating speed below 100 km/h the final proposals for limits will be given for a reference speed of 80 km/h with a 30 log (V/80) correction for data at other train speeds.

3. Policy Background

3.1 EU policy issues

An overarching policy objective of the European Union is to achieve sustainable economic development. This requires economic growth without any additional adverse environmental impact. In practice economic activity creates impacts upon the environment at both global and local levels. At the global level a reduction in the emission of “greenhouse gases”, which are responsible for global warming and associated climate change, is a major policy objective of the EU. A substantial contribution to the EU’s emissions of greenhouse gases comes from transport activity, in particular from road transport. Shifting the balance between road and rail transport (where the emission of greenhouse gas per passenger/km and tonne/km is much less), is accordingly a major objective of EU transport policy.

But transport activity also creates adverse impacts upon the environment at a local level. The two most serious impacts are local air pollution caused by the exhaust gases from internal combustion engines and noise. The significant proportion of railway operation in Europe performed by electric trains means that a shift from road to rail will reduce air pollution at the local level, with the most notable effect being experienced in urban areas. However, such a shift may aggravate the noise nuisance for local communities unless steps are taken to reduce the noise created by rail operations. At the same time it is imperative that these steps do not result in an additional cost burden upon rail transport of a scale which jeopardises the achievement of the overall policy objective of sharpening rail competitiveness and thereby ensuring the desired shift from road to rail. This paper examines the technical issues involved in reducing the noise created by rail operations and proposes noise creation limits which can be achieved without jeopardising competitiveness.

3.2 The Draft EU Directive 1983

In the late nineteenseventies and early nineteeneighties the European Commission considered it an important part of its environmental task to provide tools to control the noise created by fixed and moving machines and installations throughout the EU. The main idea even at that time was that, if limits were to be set to the noise from machinery and moving sources, this should be at a European level in order to prevent national barriers being put up against the idea of a single and common European market. Eventually European Directives have been set for the noise creation of motor vehicles (trucks, cars and motorcycles), e.g. 70/157/EEG, for the most common building and construction machinery, e.g. 84/532/EEG, for outboard ship motors, for lawnmowers (84/538/EEG) and for a range of domestic noise sources such as washing machines.

Originally the European Commission intended to include railway vehicles in their strategy. A draft Directive on the Noise Emission of Railway vehicles (KOM (83) 706 endg) was issued 7 December 1983. Although it is not specifically mentioned the draft directive applied to new vehicles only (type testing). The draft Directive included a description of a measurement method, a very crude definition of the track condition and different limit values for passenger and freight trains. The quantity to be assessed was the 25 m maximum A-weighted sound pressure level L_{Amax}. The following limit values were defined:

for passenger vehicles and locomotives: $L_{Amax} \leq 30 \log (v/100) + 89$ dB(A)

for freight vehicles: $L_{Amax} \leq 30 \log (v/100) + 92$ dB(A)

or $L_{Amax} \leq 96$ dB(A) whichever is the lower where v = vehicle speed in km/h .

The draft directive was never adopted and no further initiative was made by the EC for over ten years. During that time the railways nevertheless made considerable progress, both in sponsoring research which has provided a much better understanding of the phenomena of noise creation by railway vehicles and in equipping passenger vehicles with disc brakes which result in much lower levels of noise creation.

3.3 National Initiatives for Railway Noise creation limits

Since 1983 a few countries, (Austria, Italy and Switzerland), have taken the initiative of setting noise creation limits for railway vehicles. This section outlines the key elements in each of these national initiatives; a summary of the limit values can be found in [5].

3.3.1 Austria

Austria issued its railway vehicle noise approval directive (25 June 1993), which distinguishes 7 vehicle categories and sets limits for three periods of time, of which the last will enter into force on 31st December 2001. The limits apply to vehicles which are submitted for homologation in Austria. In case the limits cannot be complied with, the manufacturer may decide to have the vehicle homologated somewhere else, where no limits apply. When such homologation is acquired, the vehicle will then have to be admitted to the Austrian network, under the force of international agreements.

The Austrian Directive includes a measurement method which basically assesses the L_{pAmax} value (averaged over 3 passbys).

The limits applicable from 31 December 2001 can be compared to the former EC draft directive for the two main vehicle categories under consideration, i.e.

for passenger vehicles category1 and category2: $L_{pAmax} \leq 30 \log (v/80) + 80$

for passenger vehicles catetory3 and category4: $L_{pAmax} \leq 30 \log (v/80) + 83$

for freight vehicles: $L_{pAmax} \leq 30 \log (v/80) + 83$ +/- 2 dB(A)

where v = vehicle speed in km/h

The band of 2 dB(A) refers to different vehicle types. The overall limits are 6 dB(A) more stringent than the 1983 values from the draft EU directive.

Some of the objections against the EC draft directive equally apply to the Austrian method (track condition not sufficiently defined), in particular the Austrian directive defines neither rail roughness nor wheel roughness.

3.3.2 Italy

In force from:	Limit values set by current purchasing technical specifications for locomotives and passenger coaches at 250 km/h	Limit values LAmax to be met during the interval between two successive checks L_{Amax}											
		Expiry of the checks [years]		Passenger rolling stock				Freight rolling stock				Diesel Locos	DMU
				Locomotives		coaches		Locomotives		wagons			
		V≤200 km/h	V>200 km/h	250 km/h	160 km/h	250 km/h	160 km/h	160 km/h	90 km/h	160 km/h	90 km/h	80 km/h	
Da 1.1.2002	88	6	5	90	85	88	83	85	84	90	89	88	83
Da 1.1.2012	85			88	83	86	81	83	82	88	87	86	81

Rolling stock is subjected to periodic checks, to verify the certification of homologation is still valid. The checks are carried out at least every six years if the rolling stock has a service speed up to 200 km/h and every five years over this speed. The measurements are carried out in free field conditions at a distance of 25m from the track centre line and at a height of 3.5m above the upper surface of the rails. The legislation applies only to rolling stock built or heavily rebuilt after the date it has come into force. The roughness of the rails is not specified.

3.3.3 Switzerland

L_{pAmax} values were recommended in 1994 for new vehicles:

Passenger coaches, locomotives and EMU's: 80dB(A), at 80km/h, 7.5m, which is equivalent to 76 dB(A) at 100 km/h at 25 m

L_{pAmax} values were also recommended in 1994 for existing vehicles

Passenger coaches, locomotives and EMU's with disc or sinter bloc brakes: 85dB(A), at 80km/h, 7.5m which is equivalent to 81 dB(A) at 100km/h at 25m

Passenger coaches, locomotives and EMU's with Cast iron brakes: 90dB(A), at 80km/h, 7.5m which is equivalent to 86 dB(A) at 100km/h at 25m.

This is now complemented by Railway Abatement Act:

Retrofitted passenger coaches, retrofitted: 84 dB(A) TEL (80km/h, 7.5m) which is equivalent to 80 dB(A) at 100 km/h at 25 m.

Freight Wagons: Currently there are no values for freight wagons. A measurement campaign of the Ministries for Environment and Transport is expected to fix those values within the next 1-2 years.

3.3.4 Conclusion

As a conclusion strong regulations may be ineffective if the limits are too tight. Austria has set very tight values for new freight wagons; it is understood that as a consequence only a small number of freight wagons have been registered in Austria since the new limits came into force.

3.4 Recent Developments

3.4.1 EU-Directive on Ambient Noise

Over the past decade the EC has approached the question of environmental noise from the perspective of noise reception; this has culminated in the recent adoption of the ‘Directive relating to the assessment and management of environmental noise‘. The principal thrust of this Directive is to force member states to identify “hot spots” where environmental noise is excessive and to create action plans to tackle them. It is anticipated that the majority of these cases will concern road transport. Tackling the much smaller number of railway “hot spots” will probably involve a combination of infrastructure-and vehicle based measures. The details of any action plans will depend on the noise reduction required and the source of the highest noise levels in any particular location.

In its approval of the Directive on ambient noise the European Parliament has asked the European Commission to prepare proposals for noise creation limits for rail vehicles.

3.4.2 Railway noise working group: WG6-EU Commission

For the application of the EU Directive on Ambient Noise, the EU Commission has set up several working groups on noise, including specifically a Railway group (WG6).

The EU Working Group no. 6 on railway noise has initiated discussions on the issue of noise creation. As part of this initiative DG TREN commissioned external consultants led by ØDS to review best practice. The final report by the consultants has just been published. This report suggests the implementation of noise creation limits and proposes values. Unfortunately the ØDS report is selective in its assessment of the evidence and fails to reflect the body of knowledge on the subject of railway noise which has been built up by research endeavour over the past 30 years. Such a review – together with conclusions concerning achievable and affordable limit values – is the principal purpose of this paper.

The legal framework for the adoption of any noise creation limit values will be provided by the Directive on Conventional Interoperability. The Directive requires the development of Technical Standards for Interoperability (TSI) including one related to noise creation. For high speed trains TSIs have already been developed.

It has to be kept in mind that normally TSI specifications are minimum requirements for interoperability. In the case of noise creation, the limit values will be the maximum level permitted.

Currently, the question of noise creation values (and possibly limits) is addressed in a number of groups or projects, which will be briefly reviewed in the following sections

3.4.3 TSI high speed

TSI work for high speed trains, carried out within the frame of AEIF (European Association for Railway Interoperability) has incorporated the following noise limits into the TSI “Rolling Stock”[6]:

TEL=91 dB(A) at 300 km/h (25 m from track, 3.5m above rail level) for existing trainsets

TEL=88 +/-1 dB(A) at 300 km/h (25 m from track, 3.5m above rail level) for next generation of trainsets (2010)

The limits are expressed in terms of TEL measured according to the CEN Pr EN 3095.

A roughness specification for the track (proposal from WG 6) tighter than that in Pr EN 3095 has also been added.

With respect to the initial proposal from AEIF, a suggestion that a functional specification for track dynamic properties is currently under discussion.

No limit was set in the infrastructure TSI in terms of reception limits, this being considered to be the Member State responsibility (subsidiarity).

3.4.4 STAIRRS EU project

Within the frame of the EU co-funded STAIRRS project, the question of noise creation levels is addressed in both technical Work Packages (WP 1 and WP2) of the project.

In WP2 in particular, separation of the noise contributions to total rolling noise from rolling stock and infrastructure are being investigated, together with proposals for a classification of trains and tracks in terms of their noise creation.

A series of tests is currently being carried out in different locations in Europe using the same measurement protocol. These will also provide further data for noise creation of different designs.

3.4.5 CEN 3095 standard, discussions on track specification

All documents relevant to railway noise creation measurements refer to Pr EN3095 standard, which is an update of ISO 3095 standard.

However, even if significant progress has been made in the development of this standard in order to ensure a better reproducibility of the measurements (track roughness specification), the standard in its present status is not considered to provide sufficiently reproducible results because the track specification is not tight enough.

A proposal, both for track roughness and track dynamic properties was made by an ad –hoc subgroup of EU-WG6. This raises the question of carrying type tests on specially controlled tracks (low-noise) and also of the subsequent use of the results for purposes other than basic rolling stock acceptance (using the type test value for impact studies for example).

These points will be discussed in Annex 1.

3.4.6 Conclusions

Significant progress has been made in recent years in understanding the phenomenon of noise creation for both high and conventional speed trains. This has provided a much more sound basis for creating regulations which set noise creation limits for new trains than was available 20 years ago when the EC first contemplated an initiative. However further work is needed to resolve problems of reproducibility with the existing specification of measurement standard Pr EN 3095. The Railways of Europe believe that the starting point in the assessment of the potential for reducing the noise created by trains is a proper understanding of the performance of existing trains. The next chapter contains a comprehensive review of existing knowledge.

4. Technical Background

Since the question of noise creation levels from railways is not new, this chapter aims at giving background information both on historical initiatives on the subject and explaining how official values for railway noise creation are already in use in the legal process in different countries, even if formal limits are not set. Previous studies, where noise creation levels from railways were gathered from a European point of view, are also reviewed.

4.1 National Noise Prediction Models

In many countries in the EU noise prediction is required for legal procedures, e.g. in relation to new urban developments in the vicinity of existing railways or new railways close to existing dwellings. Prediction methods have been developed in the Nordic countries, in The Netherlands, in Germany, in France, in the UK, in Switzerland and in Italy. Usually the predicted value is a long term average equivalent sound pressure level at a certain reception point. The input then consists of traffic data (number of trains per train type per unit time, their speed) and track data (track type). The methods are based on experimental data from train pass-by measurements. These results can be used to obtain a “survey on the performance of existing rolling stock” which was indicated in chapter 1. However, the following conditions should be observed:

It is usually necessary to correct the “reference noise level” in the prediction method into a value which can be compared for type testing. For example, the Dutch method predicts the emission number, which is the long term average equivalent noise level at 1m distance resulting from the pass-by of 1 vehicle per hour of the type under consideration. This can in principle be corrected into a pass-by TEL, but it requires some scrutiny and also some knowledge of the vehicle (e.g. its length). Assumptions would have to be made on the properties of the ground between track and receiver point and also on wind speed and direction.

The track conditions, which form the basis of the large databases for noise prediction methods, usually reflect the average track conditions of the network under consideration. These may differ from the track conditions which are prescribed for type testing. This has to be kept in mind when comparing type testing and prediction data.

Comparison of predicted noise levels from the various national prediction schemes is given below:

4.1.1 Dutch Prediction (Reken en Meetvoorshrift, rekenmethode 1)

This uses 9 categories of trains, as based on the most recent version of the SRM. Currently a prediction equation for ICE is lacking.

For each category an Emission Number, E, is derived using the following equation:

$E = a + b \log v + 10 \log (Q) + C$

Where: a and b are constants

Q is the number of train units (coaches, wagons) per hour

C is a correction factor for the track type. For the default case of ballasted track with monobloc concrete sleepers C=0. Taking into account propagation, TEL values for a distance of 25m have been derived and are given below for each category of train for a speed of 80km/h.

Category	Description	Emission number										
		a	b	Q	C	v	E	d	LAeq	Length	tp	TEL
1	CI tread braked Intercity EMU " Mat 64"	14.9	23.6	6.0	0.0	80.0	67.6	25.0	52.5	150.0	6.75	79.8
2	CI tread braked Intercity Coaches, Double Decker Coaches and ICM EMU's	18.8	22.3	6.0	0.0	80.0	69.0	25.0	63.9	156.0	7.02	81.0
3	Disc braked Regional SGM	20.5	19.6	4.0	0.0	80.0	63.8	25.0	48.7	104.0	4.68	77.6
4	Freight (CI tread braked)	24.3	20.0	30.0	0.0	80.0	77.1	25.0	62.0	375.0	16.88	85.3
5	Diesel-Electrical EMU	46.0	10.0	2.0	0.0	80.0	68.0	25.0	52.9	52.0	2.34	84.8
6	Diesel-Hydraulic EMU	20.5	19.6	2.0	0.0	80.0	60.8	25.0	45.7	44.0	1.98	78.3
7	tram and metro	18.0	22.0	3.0	0.0	80.0	64.6	25.0	49.5	50.0	2.25	81.6
8	Disc braked and composite braked Double decker coaches, ICM EMU's and Regional EMU's	25.7	16.1	4.0	0.0	80.0	62.4	25.0	47.2	102.0	4.59	76.27
9	Thalys	22.0	18.3	10.0	0.0	80.0	66.8	25.0	51.7	224.0	10.08	77.3

4.1.2 UK Calculation of Railway Noise 1995

This prediction method is part of the UK Noise Legislation and is compulsory when carrying out railway noise predictions to assess eligibility for sound insulation for new, additional or altered railways.

It is the intention that the noise characteristics of all train types in operation in the UK will be quantified separately. To date the data base is not complete but the information below gives examples of TEL values for a number of commonly used train types at different speeds. All values are the result of regression analysis of free field measurements 25m from the track.

In the calculation method a reference noise level, SEL at 25m, is given for each train type. TEL is derived from SEL using the following equation:

TEL = SEL - 10 log $t_{p;}$ where

t_p = train pass-by time (seconds) = train length (buffer to buffer)/train speed

4.1.2.1 Cast Iron Tread Braked Passenger Vehicles

Mk I/II Intercity coaches 93.4 dB(A) @ 160 km/h (84.4 dB(A) @ 80km/h)

Class 421/422 emu 88.3 dB(A) @ 144 km/h (80.6 dB(A) @ 80km/h)

4.1.2.2 Disc Braked Passenger Vehicles

Mk III/IV Intercity coaches	87 dB(A) @ 200 km/h (75.1 dB(A) @ 80km/h)
Class 319 emu	90.1 dB(A) @ 160 km/h (81.1 dB(A) @ 80km/h)
Class 465/466 emu	83.4 dB(A) @ 120 km/h (78.1 dB(A) @ 80km/h)
Class 165/166 dmu	83.9 dB(A) @ 144 km/h (76.2dB(A) @ 80km/h)

4.1.2.3 Cast Iron Tread Braked Freight

2 axled tank	85.3 dB(A) @ 80 km/h
4 axled tank	85.1 dB(A) @ 80 km/h

4.1.2.4 Disc Braked freight

2 axle coal hopper	81.2 dB(A) @ 80 km/h
freightliner (4 axle)	82.4 dB(A) @ 120 km/h (77.1 dB(A) @ 80km/h)

German Prediction Method (Schall 03)

Noise levels are characterised by the hourly L_{Aeq} for the passage of 100m of train per hour at a speed of 100 km/h for a measurement position 25m from the track and 3.5m above track level.

TEL can be calculated from the hourly L_{Aeq} using the following equation:

TEL = L_{Aeq} + 10 log (3600/train passby time t_p)

Where

t_p = train length/train speed = 100 * 3.6/V (with V in km/h)

for V = 100 km/h

TEL = L_{Aeq} + 30

Schall 03 contains the following values for the hourly L_{Aeq}, at 100 km/h which have been converted to TEL values at 100 km/h and at the maximum speed of the respective vehicles.

Train type	L_{Aeq} @ 100km/h	TEL @ 100km/h	L_{Aeq} @ max speed	TEL @ max speed
ICE (Vmax = 280 km/h)	47.0	77.0	55.9	90.4
Disc braked passenger (Vmax = 200 km/h)	50.0	80.0	56	89.0
Cast iron tread braked freight (Vmax = 120 km/h)	58.0	88.0	59.6	90.4

4.1.4 Swiss Prediction Method SEMIBEL

In Switzerland, railway noise mapping was introduced by law in 1986 with the noise ordinance. Noise mapping was accomplished by the SBB in 1996. The maps to the scale 1:2000 covering more than 70% of the nation wide network were calculated with the support of Swiss noise creation and reception model for the calculation of railway noise SEMIBEL[2].

Parameters for the noise creation levels of each type of vehicle are basically A and B values (rolling stock dependent), train speed and train length.

For calculating the noise reception level (used to compare with the noise limits in the noise ordinance) the calculation contains a further correction value F for the track on a specific line segment in question and a correction value for rolling noise depending on the train frequency is added. A correction value F=0 means smooth track on an open line.

Below corresponding noise levels for railway noise creation in Switzerland are indicated:

Calculation of noise creation from SBB rolling stock: Leq/h and TEL values											
Brake type	P-G	L-G	L-K	L-S, L-D,	P-K, P-DK	P-KE	L-SM	G-D	P-D	G-G	G-KE
Vehicle type	EW-I/II	Re4/4, Re6/6			EW-III			RLS	EW-IV		
A =	4	3	1	-2	-2	-5	-28	-28	-28	22	15
B =	25	25	25	25	25	25	35	35	35	15	15
Fz-Länge in m =	24	18	18	18	24	24	18	18	26	20	20
	LEQ/h (in 1 Meter, A+B*log(v)+10*log(L))										
V in km/h	A=4;B=25	A=3;B=25	A=1;B=25	A=-2;B=25	A=-2;B=25	A=-5;B=25	A=-28;B=35	A=-28;B=35	A=-28;B=35	A=22;B=15	A=15;B=15
80	65.4	63.1	61.1	58.1	59.4	56.4	51.2	51.2	52.8	63.6	56.6
100	67.8	65.6	63.6	60.6	61.8	58.8	54.6	54.6	56.1	65.0	58.0
125	70.2	68.0	66.0	63.0	64.2	61.2	57.9	57.9	59.5	66.5	59.5
140	71.5	69.2	67.2	64.2	65.5	62.5	59.7	59.7	61.3	67.2	60.2
160	72.9	70.7	68.7	65.7	66.9	63.9	61.7	61.7	63.3	68.1	61.1
V in km/h	TEL-value 7.5m										
80	91.9	90.9	88.9	85.9	85.9	82.9	78.9	78.9	78.9	90.8	83.8
100	95.2	94.2	92.2	89.2	89.2	86.2	83.2	83.2	83.2	93.2	86.2
125	98.6	97.6	95.6	92.6	92.6	89.6	87.6	87.6	87.6	95.7	88.7
140	100.4	99.4	97.4	94.4	94.4	91.4	89.8	89.8	89.8	96.9	89.9
160	102.4	101.4	99.4	96.4	96.4	93.4	92.4	92.4	92.4	98.4	91.4
Explanations for brake types											
P-	Passenger		G	Cast iron		D	Disc				
L-	Locomotive		K	K-bloc		KE	K-bloc and resilient wheel				
G-	Freight wagon		S	Sinter bloc		SM	Sinter bloc and magnetic brake				

4.1.5 France

The values in official use for noise mapping and noise prediction are given below:

Rolling Stock type	Reference values			Mean length (m)	Coefficient k for propagation
	d_0 (m)	V_0 (km/h)	L_0 (dB(A))		
Suburban short trains and metros					
Category 1-assimilables à Z5300 (Z6400, MI79, MI84)	25	120	81	100[1]	16
Category 2 – assimilables à Z2N	25	120	87	100[1]	16
RER (MS61)	25	100	79	100[1]	16
Petits gabarits métro (RATP)	7.5	60	79	75	16
Passenger trains					
Intercity	25	200	96	250	15
Trains à grande vitesse (TGV)					
First generation (none currently in service)	25	270	99.5	200[1]	15
second generation	25	300	94.5	240[1]	15
Trains de fret	25	100	88	325	12
Single units/EMUS					
Autorails et automotrices électriques bicaisses	25	120	87	40[1]	20

Trains derived from standard types:

Rolling Stock type	Reference values			Mean length (m)	Coefficient k for propagation
	d_0 (m)	V_0 (km/h)	L_0 (dB(A))		
Passenger trains and regional(TER)	25	200	96	125	16
TGV PSE oranges revamped	25	300	94.5	200[1]	15
TGV réseau et Thalys	25	300	94.5	200[1]	15
TGV 2 Niveaux	25	300	92	200[1]	15
Rames Eurostar	25	300	94.5	400	15
Freight	25	100	88	200	15

With: d_0, distance where reference level L_0 is given, V_0, reference speed for which L_0 is given, L_0, reference level (TEL) for each type of train, k, propagation constant depending on train length.

[1] Length of single unit

4.1.6 Conclusions

At 80 km/h and 25m the different national prediction models give the following noise levels for different generic train categories

	Tread braked passenger	Disc braked passenger	Tread braked freight
Holland	80 – 81	76 – 78	85
Germany	85	74* - 77	85
Switzerland	85	72-74	84
France	87	76	88
UK	80 – 84	75 – 81	85

* ICE with wheel dampers on track with stiff rail pads

This would suggest that current practice for trains in service as recognised by laws in different countries give the following noise levels (TEL) at 25 m from the track:

4 axled disc braked passenger vehicles	75 dB(A) @ 80 km/h
	84 dB(A) @ 160 km/h
	87 dB(A) @ 200 km/h
tread braked freight vehicles	85 dB(A) @ 80 km/h
	88 dB(A) @ 100 km/h
	90 dB(A) @ 120 km/h

4.2 Noise creation values of different existing rolling stock

4.2.1 Measuring noise creation: some problems

For many years interpretation of empirical data has been complicated by the spread of observations even for a single vehicle type at the same site; it is normal for this spread to be at least 2 dB (A).

The traditional method of analysis has been to carry out best fit regression to the data to quantify this trend with speed. Thus for a standard deviation of 2 dB (A), 5% of the data will be more than 4 dB(A) noisier than the average and 5 % will be more than 4 dB (A) quieter. This demonstrates the potential pitfalls of inferring general trends from single measurements or even from a small data base of measurements.

4.2.2 1996 survey on noise creation data

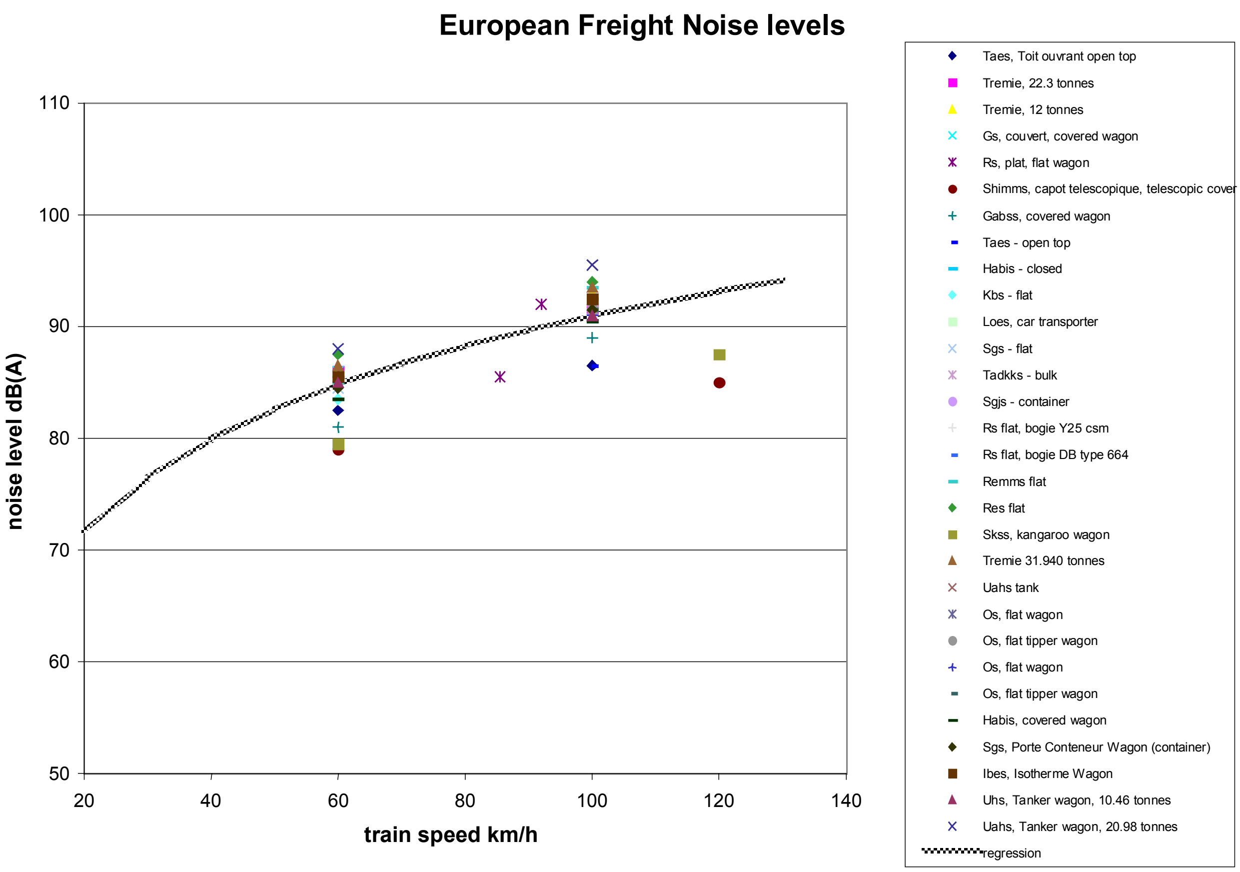
In 1996 ERRI Committee C163 commissioned BR Research (now AEA Technology Rail Ltd) to review the then current version of the CEN 256 WG3 proposal for the revision of ISO 3095. Part of that review contained an update of noise measurements of European passenger and freight trains provided by European railway administrations. Data was provided for free field noise levels (L_{Amax} or TEL) 25m from the track, at different speeds for a number of vehicles on what was designated "good quality track". A summary of that data is given below.

4.2.2.1 Cast Iron Tread Braked Freight Vehicles

The figure below gives noise levels for cast iron tread braked freight vehicles. Also shown in the figure is the best fit regression curve, given by the equation:

$$L_A = 91 + 28 \log (v/100)), \ v = \text{train speed in km/h}$$

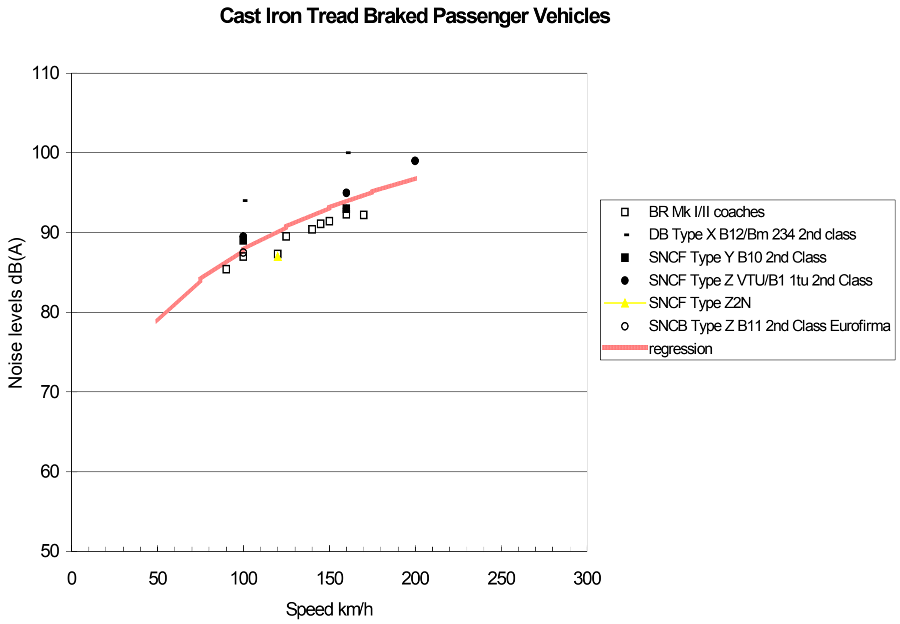
At 100 km/h the regression equation gives a value of 91 dB(A).



Cast Iron Tread Braked Passenger Vehicles

The figure below shows similar data for cast iron tread braked passenger vehicles. The best fit regression curve is given by:

$$L_A = 88 + 30 \log (v/100), \text{ v= train speed in km/h}$$



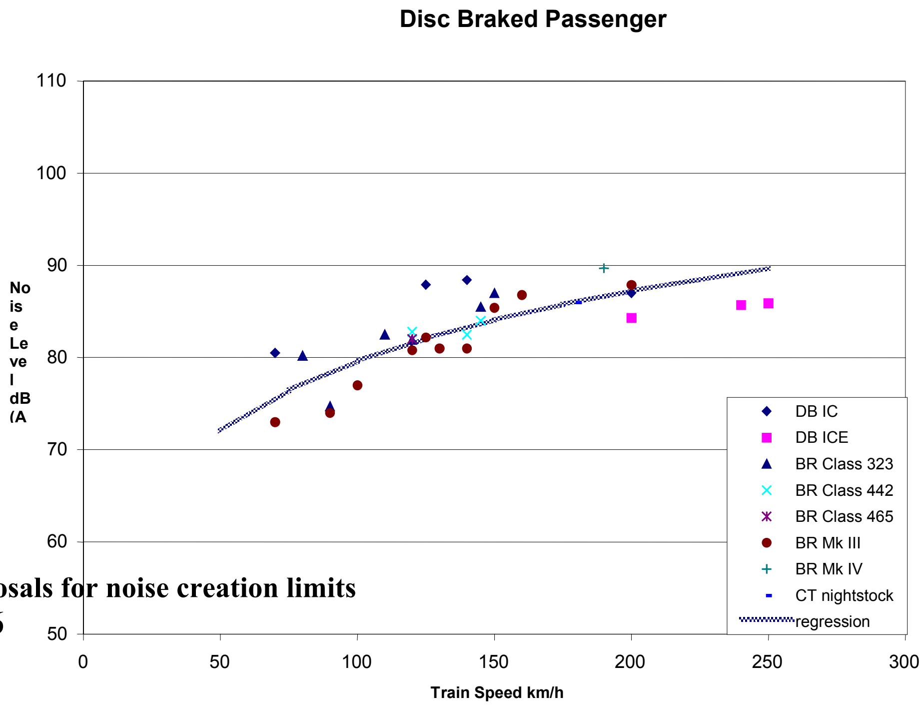
At 100 km/h this predicts a level of 88 dB(A) and at 160 km/h a level of 94 dB(A). This indicates that cast iron tread braked passenger vehicles are about 3 dB(A) quieter than cast iron tread braked freight vehicles at the same speed.

4.2.2.3 Disc Braked Passenger Vehicles

For disc braked passenger vehicles the best fit regression curve is given by:

$$L_A = 80 + 25 \log (v/100), \text{v= train speed in km/h}$$

At 100 km/h this predicts a level of 80 dB(A), at 160 km/h a level of 85 dB(A) and at 200 km/h a



level of 87 dB(A). This confirms the well know result that disc braked vehicles are approximately 10 dB(A) quieter than cast iron tread braked vehicles. (This analysis shows – 9 dB(A) at 160 km/h)

4.2.2.4 Conclusions

Although there were differences in the actual measurement techniques of the different railway administrations, these results gave a reasonable indication of the current noise levels for service trains and showed good agreement between different countries.

Noise levels from this study, measured 25m from the track, could be summarised as:

Cast Iron tread braked freight @ 80 km/h	= 88 dB(A)
Disc braked passenger vehicles @ 80 km/h	= 77 dB(A)
Cast iron tread braked passenger vehicles @ 80 km/h	= 85 dB(A)
Cast Iron tread braked freight @ 100 km/h	= 91 dB(A)
Disc braked passenger vehicles @ 100 km/h	= 80 dB(A)
Cast iron tread braked passenger vehicles @ 100 km/h	= 88 dB(A)
Cast iron tread braked passenger vehicles @ 160 km/h	= 94 dB(A)
Disc braked passenger vehicles @ 160 km/h	= 85 dB(A)

It should be noted that the ICE data points, relevant to train sets equipped with wheel absorbers pull down the regression curves, additionally BR vehicles have their disc pads mounted on the web of the wheel.

These results are reasonably consistent with the noise prediction levels summarised in section 4.1, although they would indicate that current national prediction schemes assume cast iron tread braked freight vehicles to be about 3 dB(A) quieter (from 88 dB(A) to 85 dB(A) @ 80 km/h) than these measurements.

These figures, cross-checked with an updated review of noise creation levels, will be used to develop proposals for future noise creation levels.

4.2.3 Updated overview of noise creation values for different existing rolling stock

This chapter aims at giving an updated overview of noise creation values for different existing rolling stock.

4.2.3.1 Typical present values

From data provided by various operators noise levels of different types of rolling stock were categorised by type of braking and plotted in the left figures below:

The following symbols are used to define braking type categories:

D: Disc

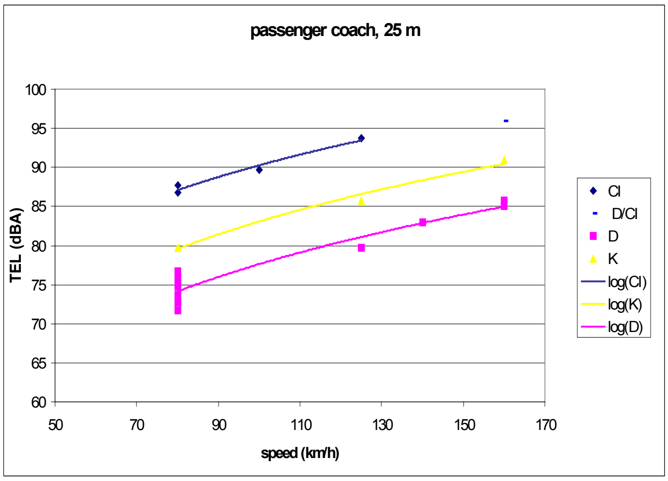
CI: Cast iron

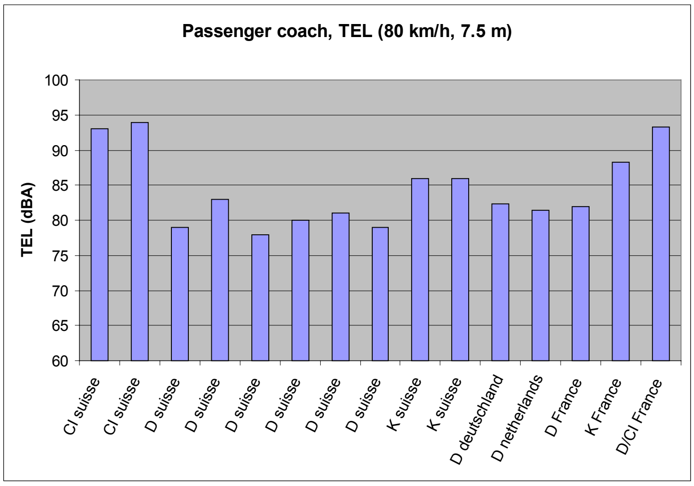
K: K composite blocks

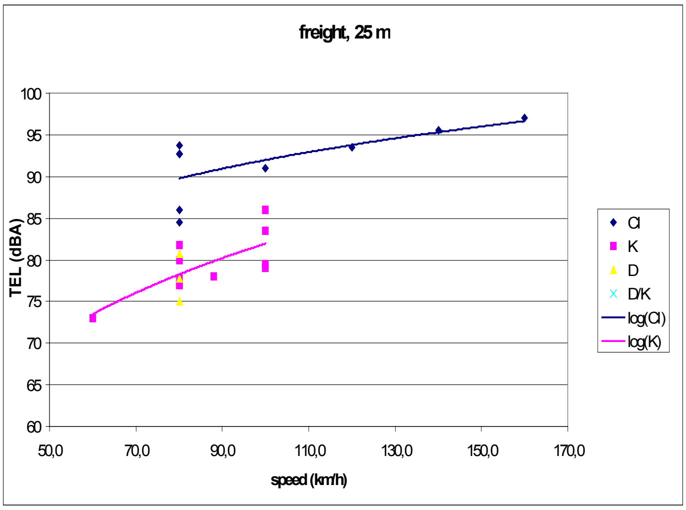
SI: Sintered

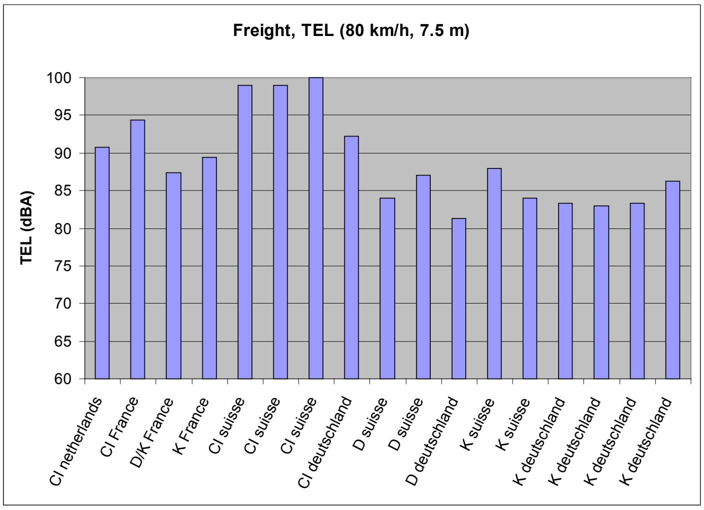
The regression coefficients obtained for speed dependant curves which are shown in the left figures, are quite significant ($R^2 > 0.90$).

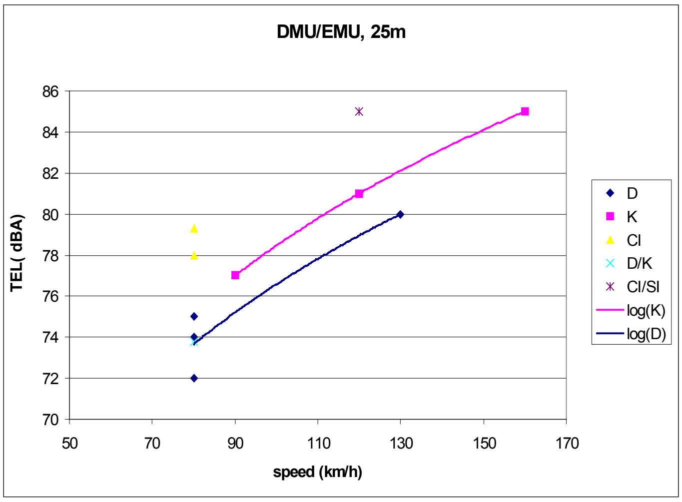
In the following all data were gathered into a single dataset and converted into TEL (80,7.5m) to provide a global picture of the situation with respect to the proposals of the Study for the Commission.

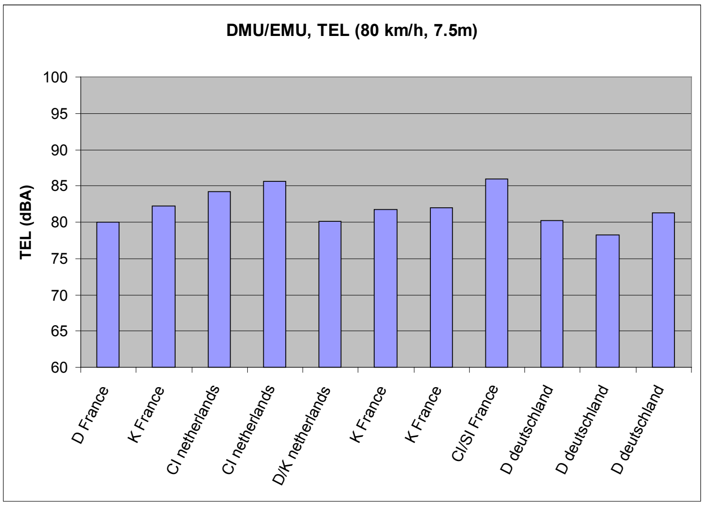


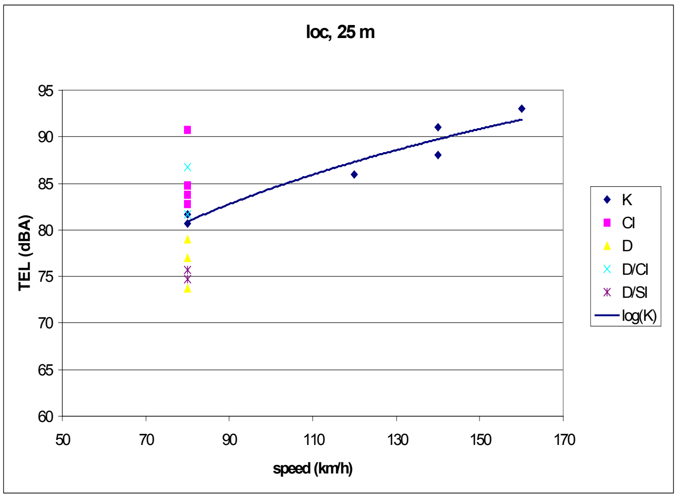


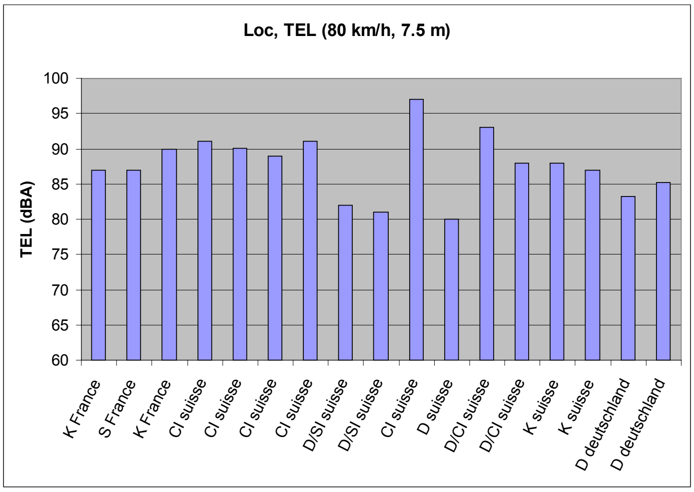

freight, 25 m
TEL (dBA)
speed (km/h)
100
95
90
85
80
75
70
65
60
50,0
70,0
90,0
110,0
130,0
150,0
170,0
CI
K
D
D/K
log(CI)
log(K)


Freight, TEL (80 km/h, 7.5 m)
TEL (dBA)
100
95
90
85
80
75
70
65
60
CI netherlands
CI France
D/K France
K France
CI suisse
CI suisse
CI suisse
CI deutschland
D suisse
D suisse
D deutschland
K suisse
K suisse
K deutschland
K deutschland
K deutschland
K deutschland


DMU/EMU, 25m
TEL((dBA)
speed (km/h)
86
84
82
80
78
76
74
72
70
50
70
90
110
130
150
170
D
K
CI
D/K
CI/SI
log(K)
log(D)


DMU/EMU, TEL (80 km/h, 7.5m)
TEL (dBA)
100
95
90
85
80
75
70
65
60
D France
K France
CI netherlands
CI netherlands
D/K netherlands
K France
K France
CI/SI France
D deutschland
D deutschland
D deutschland


loc, 25 m
TEL (dBA)
speed (km/h)
95
90
85
80
75
70
65
60
50
70
90
110
130
150
170
K
CI
D
D/CI
D/SI
log(K)


Loc, TEL (80 km/h, 7.5 m)
TEL (dBA)
100
95
90
85
80
75
70
65
60
K France
S France
K France
CI suisse
CI suisse
CI suisse
CI suisse
D/SI suisse
D/SI suisse
CI suisse
D suisse
D/CI suisse
D/CI suisse
K suisse
K suisse
D deutschland
D deutschland

The difference in noise creation at 80km/h of each category clearly appears in the above figures. These levels at 80 km/h are taken as starting points for the limit proposals in ch.5.

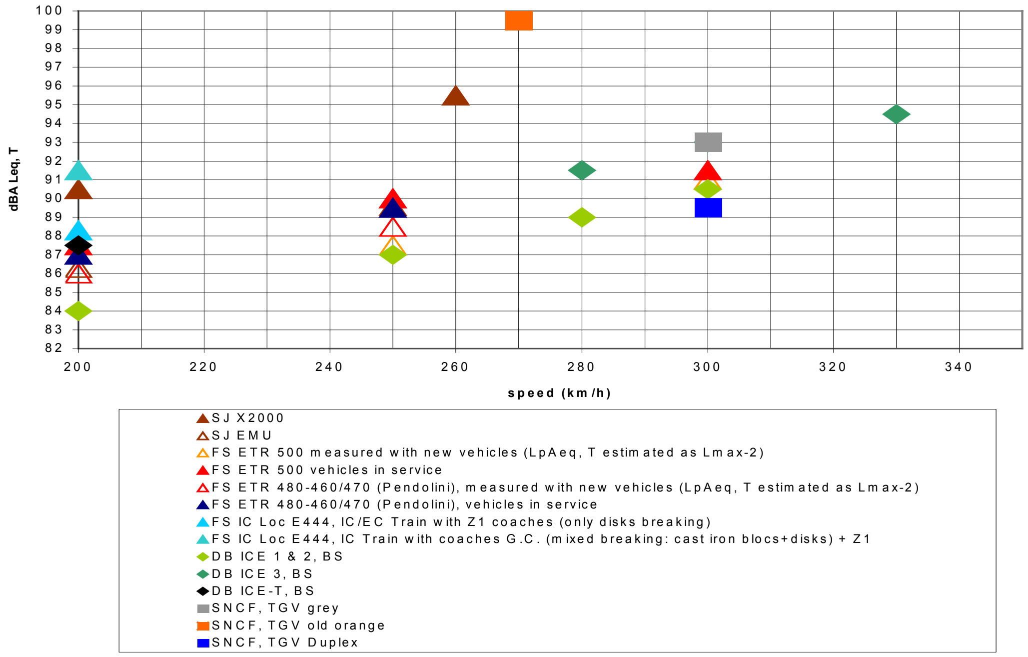
4.2.3.2 Conclusion

From this overview, current noise levels can be summarised as follows:

Cast Iron tread braked freight @ 80 km/h at 25m (7.5m)	= 85 (92) dB(A)
Disc braked passenger vehicles @ 100 km/h at 25m (7.5m)	= 78 (85) dB(A)
Disc braked passenger vehicles @ 160 km/h at 25m (7.5m)	= 84 (91) dB(A)

4.2.3.3 High Speed Trains

A synthesis of levels of high speed trains in Europe, is given below:



This figure shows the changes in noise level between the first generation TGV (SNCF, TGV old orange) and the latest generation (SNCF, TGV Duplex). The noise reduction (in excess of 10 dB(A)) is the result of changing the brakes on all wheels from cast iron tread brakes to disc brakes.

The lower noise levels from the disc braked TGV compared to the disc braked ICE are because, by having articulated bogies, the TGV has fewer noise sources for a given length of train.

Thus TGV Duplex gives the lowest noise levels for high speed trains currently in service.

4.3 Noise Reduction potentials

4.3.1 Research projects results

4.3.1.1 Rolling noise reduction

A number of research projects have been carried out for the past ten years, aimed first at providing a better understanding of rolling noise - since this was identified as the major noise source for railways at conventional speeds - then at developing prototype solutions of reduced noise systems.

Significant work was carried out by "ERRI C163" committee, which gathered together railways' experts and other known experts in the field (ISVR, TUBerlin, BBN…). This led to the development of TWINS ("Track Wheel Interaction Noise Software") which has been validated against a wide variety of situations in Europe [13, 14].

The basic results that came out of rolling noise research were that the following two steps had to be considered for rolling noise reduction

4.3.1.2 Reducing roughness on both wheel and rail:

Smooth wheels and rails can reduce both the wheel and track components of rolling noise. Wheel roughness is controlled by the type of braking used and for some years the use of disc brakes on passenger vehicles has shown a reduction of about 8 dB(A) when compared to the noise from cast iron tread braked vehicles at the same speed. Similar results can be achieved with composite brake blocks although it is likely that the benefit will be reduced because residual stress problems with wheels with this form of braking mean that it is not possible to acoustically optimise the wheel cross sectional shape.

Using disc brakes on trailer bogies of TGV gave a significant reduction in rolling noise levels. Further implementation of composite brake blocks provided an extra 1-2 dB(A) reduction. Finally, TGV DUPLEX double decker train sets, which are disc braked only, are about 10 dB(A) quieter, at the same speed, than the first generation (TGV-PSE: orange train- sets).(see 4.2.3.3) The latter trains are now all revamped with composite brake blocks on motor coaches and disc braked trailer coaches.

A number of railway administrations are currently looking at rail grinding, based on acoustic criteria, as a means of noise reduction. DB uses "acoustic grinding criteria" in dedicated cases, which allows a reduction of 3 dB(A) relative to track with normal roughness.

4.3.1.3 Reducing vibration or radiation from both wheel and track components:

EU/UIC projects provided background information on rolling noise reduction that could be obtained by the use of different low noise components.

In addition to smooth wheels and rails, wheel noise can be reduced by:

- optimisation of the cross section to minimise axial response due to radial forces
- reduction of wheel diameter
- additional damping
- screening of the web

Track noise can be reduced by:

- Use of stiff rail pads
- Rail tuned absorbers
- Reduction of rail foot width

- Optimised sleeper

The reduction of overall rolling noise by such measures depends on the effectiveness of each measure in reducing the wheel or track component of noise and the balance of initial contribution of wheel and track.

Total rolling noise is the sum of wheel radiated noise and track radiated noise. The balance between these sources, given in the equation below, varies with detailed design of wheel and track and operating conditions.

$L_{TOT} = 10 \log (10^{LWHEEL/10} + 10^{LTRACK/10})$

Where:

L_{TOT} = total rolling noise

L_{WHEEL} = wheel radiated noise

L_{TRACK} = track radiated noise

When considering noise mitigation that affects only the wheel component or the track component it is necessary to consider the contribution each makes total noise.

If $L_{WHEEL} - L_{TRACK} \geq$ 10 dB(A), wheel treatments in isolation will be more effective.

For instance, when high speed vehicles operate on tracks with hard rail pads, wheel noise will tend to dominate over track noise. In this situation low noise wheel components such as wheel dampers may be effective. An example is the ICE operating on high speed DB tracks.

If $L_{TRACK} - L_{WHEEL} \geq$ 10 dB(A), wheel treatments in isolation will be ineffective.

For tracks with softer rail pads (the more normal situation in Europe) and at lower speeds, track noise will dominate over wheel noise. In these situations low noise wheel components in isolation will be ineffective and quieter railways will only result when measures are first applied to the track. This was demonstrated in the Silent Track project.

The development of noise optimised components for freight traffic was initially undertaken by ERRI, following UIC directives in 1992-1993 in the “OF-WHAT”(Optimised Freight Wheel and Track) project. Noise reductions at 60 and 80 km/h were obtained ranging from 4 dB(A) (for track measures) to 7 dB(A) (for a combination of track and wheel solutions) [15].

Experimental results obtained with prototype test wheels on a test track confirmed TWINS calculations carried out before the tests.

As these results looked promising, further developments of more industrialised prototypes were undertaken, in cooperation with the industry in the EU projects SILENT FREIGHT and SILENT TRACK.

Again similar results were obtained, as predicted by TWINS, but this time for different designs of prototype wheels on two kinds of prototype tracks.

Perforated AD860F with ring damper, (ABB/CAF manufacture)

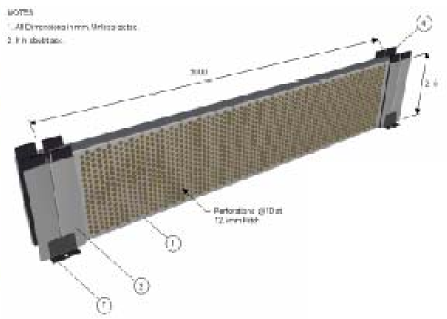
ISVR860F with Web Screens (Valdunes manufacture)

ISVR 860F with Tuned Absorber (Valdunes manufacture)

Figure 25 Detail of tuned rail absorber

Furthermore, concepts of bogie shrouds coupled with low track side barriers were also investigated:

Figure 20: Photograph of shroud, barrier combination



The compliance of the latter concepts with UIC gauge resulted in a reduced acoustic efficiency.

In determining the potential reduction deriving from low noise wheel or track designs it is important to identify the reduction in wheel noise component for low noise wheel designs and the reduction in track noise component for low noise track designs. The results from Silent Freight and Silent Track are given below:

	Estimation of Reduction in wheel component of rolling noise dB(A)
Reference wheel	0
Optimised wheel + wheel tuned absorber	7
Optimised wheel + wheel web shields	9

	Estimation of Reduction in track component of rolling noise dB(A)
Reference track	0
Rail tuned absorber	5 - 6
100mm rail foot width + rail tuned absorber	7

The above reductions show little dependence on train speed and can thus be applied to both low speed and high speed operation. The effect on the reduction of total noise will be dependent on train speed however since this is known to be one variable which affects the relative contributions of wheel and track to total rolling noise.

A general overview of the SILENT FREIGHT/SILENT TRACK results is given below (values valid for a speed of 100km/h):

	Reference Track	Retrofit solutions			New Track Design	
		optimised pads	reference pads + tuned absorbers	optimised pads + tuned absorbers	without tuned absorbers	with tuned absorbers
Reference wheel (920 mm)	0	2.1 (3.2)	5.4 (6.7)	4.4 (5.9)	2.7 (3.3)	6.1 (7.4)
Ref Wheel + ring damper	-0.3 (-0.4)	1.9 (2.8)	4.7 (5.6)	3.1 (4.2)	3.3 (3.9)	6.1 (7.1)
Perforated wheel (860 mm)	-0.4 (-0.3)				1.9 (2.1)	
Perforated wheel + ring damper	-0.2 (-0.5)	2.1 (2.6)	5.6 (6.2)	4.3 (5.1)	2.2 (2)	5.8 (6)
Optimised wheel (860 mm)	0.8 (0.9)				2.7 (3)	
Optimised wheel + shields	1.1 (0.9)	2.7 (3.2)	6.7 (7.1)	5.4 (6)	3.9 (3.9)	8.0 (8.1)
Optimised wheel + tuned absorbers	1.1 (0.8)	2.6 (3)	6.9 (7.2)	5.6 (6.2)	4.2 (4.1)	7.7 (7.8)

Table 2 overall measured noise reduction, corrected for roughness [dB(A)]

In brackets : noise reduction estimated with the Silent Freight / Silent Track tread braked reference roughness

These projects confirmed the fact that track noise exceeded wheel noise and demonstrated that overall rolling noise reductions could be obtained ranging from 4dB(A), for optimised tracks to nearly 8dB(A), for a combination of track and wheel solutions.

The prototype designs developed in these projects have still to be put into practice in terms of the industrial application and international homologation.

Similar results have been obtained in France with a national project dealing with high speed trains. The rolling noise component was reduced by 4 to 7dB(A) for trailer bogie wheels on TGV for speeds ranging from 160 km/h to 300 km/h [16].

4.3.2 Case Studies Freight and Passenger at conventional speeds

Apart from freight wagons, where technology has not improved in recent years, significant progress has already been made for most conventional and high speed applications.

In terms of conventional speed, the introduction of disc-brakes in many applications for long distance passenger coaches (except France) has resulted in nearly 10 dB(A) noise reduction.

Further progress could come from wheel absorbers (if not implemented yet) which appear to be efficient only on stiff tracks (-3 to -5 dB(A)) or tracks equipped with track absorbers, the observed overall reduction in total noise was 7-8 dB(A).

The cost of wheels equipped with absorbers (twice the cost of a classical wheel) has to be kept in mind.

For freight wagons, considering the cost of disc brakes which cannot be afforded by operators, composite brake blocks are being assessed and are currently in the process of being approved by UIC for international use. It has to be kept in mind that the composite brake block technology, by keeping braking on the wheel makes the implementation of wheel absorbers (higher wheel temperatures) or the acoustic optimisation of the wheel shape for minimising radiated noise (residual stress issues) more problematic. (see also 4.3.3.2)

Locomotive technology still has to work on either disc brakes as in Germany, or wheel absorbers, which already exist on the Lok 2000(Switzerland). Moreover, cooling fans and their circuits may be acoustically optimised.

These issues will be addressed in assessing the potential effectiveness of different treatments for various train system designs.

In the following, an assessment of potential reductions to be obtained for different cases has been derived using TWINS simulations and the result of EU projects SILENT FREIGHT and SILENT TRACK. The main important cases of freight and intercity passenger vehicles are presented.

4.3.3 Freight Vehicles

4.3.3.1 Current freight vehicle noise levels

Cast iron tread braked: 88 dB(A), 25m @100km/h (based on levels predicted by national prediction models)

Design Features: 920 mm diameter wheels to standard UIC/ORE design

disc braked: 80.4 dB(A), 25m @ 100 km/h (based on UK Freightliner)

Design Features: straight webbed wheels and web mounted disc blocks; ie optimised cross section

Using the results from Silent Freight and Silent Track projects and further modelling with TWINS, the following predictions for the effectiveness of design changes to wheels and tracks have been derived:

Design	Predicted noise Reduction dB(A)	Noise level 25m, 100 km/h TEL	Noise level 25m, 80 km/h TEL
Current (Starting point)		88	85
Composite brake (no shape optimisation)	3 – 4	84 – 85	81 – 82
Disc brake including shape optimisation	8	80	78
Wheel tuned absorbers	0	88	85
Wheel web shields	1	87	84
Composite brake + wheel tuned absorbers	4 - 5	83 – 84	80 – 81
Composite brake + web shields	5 – 6	82 – 83	79 – 80
Rail tuned absorbers	1 – 5	83 – 87	80 – 84
Wheel tuned absorber + rail tuned absorber	3 – 7	81 – 85	78 - 82
Composite brake + rail tuned absorber	3 – 8	85 – 80	82 – 77
Disc brake + rail tuned absorber	5 - 10	78 - 83 -	75 – 80
Disc brake + wheel tuned absorber + rail damper	8 - 14	74 – 80	71 - 77

4.3.3.2 Comments

Low Noise wheel components

Because of the dominance of track radiation, vehicle treatments in isolation, that do not affect wheel roughness will have little effect on total rolling noise, therefore claim by ODS that optimised wheels or wheels with dampers will reduce noise by 3 dB(A) is false. It has already been pointed out that optimisation of shape is inconsistent with composite tread braking due to residual stress issues.

A disc braked wheel with straight web is already optimised in shape therefore no further optimisation can be carried out.

Smooth wheels

Current TWINS predictions show disappointing benefit from smooth wheels without shape optimisation ie wheels with composite brake blocks. This will need to be reviewed as more measurement data becomes available.

Wheel treatments + rail damping

Once the smooth wheel and rail situation has been achieved the only way further appreciable reductions in rolling noise can be achieved for freight vehicles is when rail damping is used in addition to wheel treatments.

In such a situation, a level of about 75 dB(A) (79 dB(A) at 7.5m, 80km/h) seems to be the lowest achievable with current knowledge.

A further 2 to 3 dB(A) reduction could be obtained by using bogie shrouds and low trackside barriers, which would have to comply to international gauge limitations, and would imply major changes both in hot axle –box detection and wheel maintenance practices.

Acoustic grinding is predicted to have little benefit at these train speeds.

4.3.4 Passenger Coaches

4.3.4.1 Current Levels

4 axle disc braked passenger vehicles 75 dB(A) @ 25m, 80 km/h (DB value 76)

84 dB(A) @ 160 km/h

87 dB(A) @ 200 km/h

4.3.4.2 Design Features

4 axled disc braked, straight webbed wheels with either web mounted or axled mounted disc blocks, ie optimised cross section, 4 noise sources per 23m approximately

From modelling with TWINS, the following predictions for the effectiveness of design changes to wheels and tracks have been derived:

Design	Predicted Noise Reduction dB(A)	Passenger coaches Noise level 25 m, 160 km/h	Passenger coaches Noise level 25 m, 80 km/h
Current	0	84	75
Smooth wheels/Composite Brake (no shape optimisation)	0	84	75
Disc brake (including shape optimisation)	0	84	75
Wheel tuned absorbers	0 – 1	83.5	74.5
Wheel web shields	1 – 2	82.5	73.5
Damped Track & Wheel	7	77	68

As a conclusion, lower levels than 73 dB(A) (80 km/h, 25 m) can only be achieved with damping measures applied on track. Such measures would make further known technological mitigation options (eg damped wheels) more efficient and would allow overall levels lower than 70dB(A) to be achieved.

4.3.5 High speed

It has to be recalled that much progress has already been achieved on noise for high speed trains with for example the introduction of disc- brakes on the trailing cars of the French TGV's. The total noise reduction from the first series (TGV-PSE) to the latest (TGV Duplex) reaches nearly 10dB(A), at equivalent speed. Experiments similar to SILENT FREIGHT/SILENT TRACK, carried also on high speed trains in France (MONA-RONA-VONA projects) demonstrated a potential of 7 dB(A) reduction coming from the association of wheel and track absorbers.

The following results were obtained:

Track absorbers only: 3-4dB(A),

Wheel absorbers on their own: practically nothing

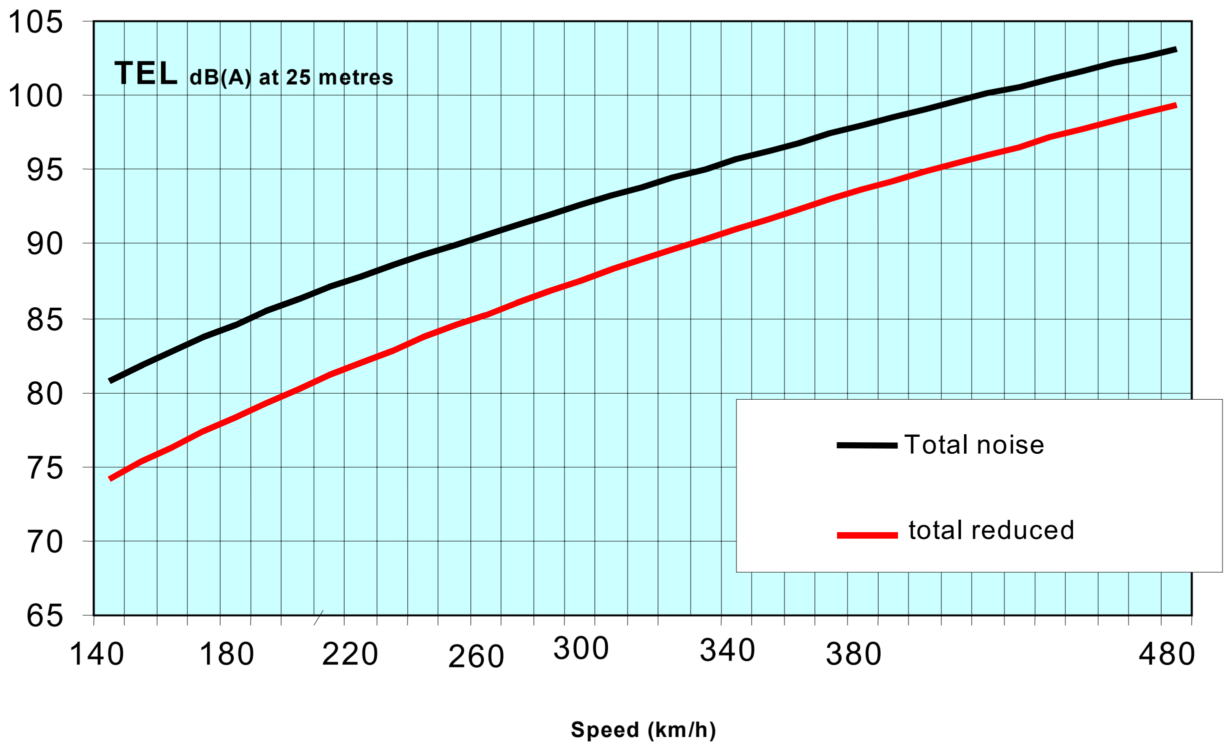
Wheel absorbers on DB track : 4dB(A)

This emphasises the need to know the respective contribution of wheel and track to total noise.

The reduction of rolling noise already carried out emphasised the potential importance of aerodynamic noise which was the field of important research programmes (DEUFRAKO, ATREBAT….)

As an example, the following diagram shows the noise reduction obtained for a typical high speed train set, where 7 dB(A) reduction has been achieved for rolling noise and 3 dB(A) reduction of aerodynamic noise. The result just meets the needs of the present recommendations from the Commission which appear to be rather theoretical than practically achievable requirements.

On the figure below the case of a current High speed train on operational track (black) is compared to the one of the same train equipped with wheel and track dampers, and bogie shrouds on motor coaches (red):



5. Proposals for Values

5.1 Basic requirements

In all cases the defined limits had to be (1) achievable and realistic and (2) controllable. These two conditions imply that the general order of activities and decisions would be as follows:

- define a measurable and relevant quantity by which the noise production of the source under concern is to be expressed and define a suitable, reproducible and accurate method by which the quantity can be assessed,
- carry out a complete market survey (using the method defined in step 1) in order to assess the performance of products presently available on the market, set different limits for new products and decide on a gradual stepwise strengthening of these limits.

5.2 Conventional speeds

The following proposal can be made for conventional rolling stock, considering the current state of technology of rolling stock and the achievable noise reductions studied above.

Interoperable trains

Short term: when TSI come into force for design starting at that time

Long term design: starting 10 years from now

It is important to note that no track measures have been considered in the suggested limits. This indicates that based on current knowledge long term objectives are similar to short term objectives.

	Conventional Railway Systems	**UIC Proposal: Pass-by TEL(80,25m)**	**UIC Proposal Equivalence: Pass-by TEL(80,7.5m)**	**ODS report: Pass-by TEL(80,7.5)**
Diesel locomotives	Short term new	78	85	80
	Long term new	78	85	78
Electrical locomotives	Short term new	77	84	80
	Long term new	77	84	78
EMU’s	Short term new	74	81	80
	Long term new	74	81	78
DMU’s Cond	Short term new	74	81	80
	Long term new	74	81	78
Passenger coaches	Short term new	73	80	75
	Retrofit	78	85	80
	Long term new	73	80	72
Freight wagons	Short term new	80	87	81
	Retrofit	80	87	85
	Long term new	(1)78 (2)75	85	77

(1) k block, (2) disc brakes

The values proposed by UIC are based on existing trains on good track conditions. On test type track conditions they may be 2 dB lower. This must be verified for different train types by tests and measurements in the same way as it is currently foreseen for high speed trains.

Because of the dominance of track radiation, low noise wheel components as isolated noise mitigation measures will have little effect on total rolling noise. It is recognised however that future lower levels would be achievable if noise mitigation measures applied to tracks were to be considered in addition to low noise wheel designs. Even then noise levels are higher than proposed in the ODS report.

High Speed

The following proposals are suggested for High Speed Trains. These values are recommended to be substituted to those currently adopted by AEIF. They are understood to be relevant to the measurement conditions suggested above.

5.3.1 Preliminary remarks:

Before implementing these values, an experimental verification of their applicability should be carried out at European level. These measurements are necessary to provide significant values for speeds higher than 330km/h.

For that reason, any proposal for speed 350 km/h has to be delayed until experimental test results are available.

The following limit values are suggested:

=Chapter in TSI	250 km/h	300 km/h	320 km/h
4.1.8 future rolling stock	88 dB(A)	91 dB(A)	92 dB(A)
7.3.2 existing rolling stock	88 + 2 dB(A)	91 + 2 dB(A)	92 + 2 dB(A)
7.4.2 recommendation for 2010	86 ± 1 dB(A)	89 ± 1 dB(A)	

5.3.2 Comments:

Retrofit of existing rolling stock is technically difficult and economically unrealistic. Therefore a permanent specific case is required, on the basis of a maximum 2 dB(A) noise increase with respect to point 4.1.8 limit values. This clause has to be also applied in the case of exercising of current order option.

5.4 Stationary noise

This chapter covers the noise emitted by vehicles at standstill, i.e. in the stations. The proposals below are based on current specifications for rolling stock and include progress from the existing situation.

	Conventional railway Systems	**UIC Proposal: LAeq7.5m**	ODS LAeq7.5m
Diesel locomotives	Short term new	**75**	75
	Long term new	**75**	75
Electrical locomotives	Short term new	**75-73 idling**	75
	Long term new	**75-73 idling**	75
EMU’s	Short term new	**65**	63
	Long term new	**65**	63
DMU’s	Short term new	**73**	73
	Long term new	**73**	73

Passenger coaches	Short term new	65	60
	Long term new	65	57

5.5 Achievability of values suggested in ODS report

It appears clearly that the values suggested in the ODS report are not at all coherent with the present situation in Europe, not only in terms of general values of noise of current type of rolling stocks, but even in terms of latest generations and progress to be expected. One can consider for example disc-braked electric locomotives on DB, TGV Duplex, or even disc-braked passenger coaches(DB).

The identified gaps are as follows:

4 to 7 dB(A) for locomotives

1 to 3 dB(A) for EMUs and DMUs
6 to 8 dB(A) for passenger cars

2 to 8 dB(A) for freight wagons

A gap still exists even if tuned absorbers are used on the rails.

For high speed, the following comments can be made:

Concerning the target values recommended by the Commission following ODS for 2005:

- The values are theoretical ones, corresponding to research objectives. Industrial developments would only lead to practical applications later than 2005. The target of 2010 seems more realistic.
- Concerning the example case developed in ODS report, much progress was already achieved through the wheel absorbers. Further progress involving skirts has other system implications involving safety aspects (axle boxes and wheelset temperature) deserving careful study.

On the other hand, although research results showed a potential 3dB(A) noise reduction for aerodynamic noise from the lower part of the train, these results could not be obtained with the experiments already carried out so far.

Analysis of costs

In recent years a number of studies have been carried out where the cost effectiveness of different railway noise control options have been compared with the traditional use of trackside noise barriers and sound insulation in nearby property.

These studies include:

- A cost benefit study carried out in 1999 for UIC
- An economic study for Silent Freight, Silent Track and Eurosabot projects (1999- 2000)
- An extension of the 1999 study to cover the whole of the EU and parts of Europe in the STAIRRS project and
- Costs associated with the implementation of composite brake blocks on freight vehicles in the UIC Noise Reduction Action Plan

STAIRRS and the UIC action plan are current but the earlier studies concluded that the use of low noise components on wheels and tracks provided alternative means, at competitive costs, of achieving target environmental noise reception levels with a greatly reduced requirement for high lineside noise barriers.

Implementation of such designs would have a significant positive effect on the visual impact of a railway incorporating noise control at source.

Both track and vehicle measures were included in the studies with the acoustic benefit determined from the results of EU projects Silent Freight, Silent Track and Eurosabot. Costs were provided by a number of sources including the industrial partners in those projects.

Smooth wheels and smooth rails are essential elements of a low noise railway system and the first step in achieving this will be the replacement of cast iron tread brakes on freight vehicles with brake blocks made of composite materials. Cost studies from the UIC project indicate the following refitting costs for these brakes.

	2 axled-cars		4 axled-cars	
	With exchange of wheels	Without exchange of wheels	With exchange of wheels	Without exchange of wheels
K – Shoes	5.961 €	3.756 €	9.881 €	5.471 €

The indicated costs are the average cost per wagon in EURO.

Smooth rails may be achieved by additional maintenance through rail grinding which currently costs SNCF, on average, 4.6 EURO per track metre per year. Additional grinding will increase this cost.

To achieve the noise levels indicated in Section 4.3 of this report smooth wheels and smooth rails will be insufficient and further measures will need to be applied to vehicles and track.

For freight vehicles, track noise tends to dominate vehicle noise (see Section 4.3), therefore further reduction of freight vehicle noise can only be achieved if low noise track measures are implemented. Currently the only known solution is the rail tuned absorber developed in the Silent Track project. Costs for these absorbers were included in the economic study carried out for Silent Track, Silent Freight and Eurosabot projects. Because the inclusion of rail absorbers is critical in an effective noise control programme their costs are a dominant factor in providing a cost effective option. The economic study showed that a unit cost of 200 EURO per track metre (fitted) was necessary to achieve this objective.

The suppliers are confident that this can be achieved in volume production.

It can be assumed that if wheels are replaced at the end of their useful life there will be no additional cost associated with providing a wheel to which noise reduction measures are to be attached. There will be an additional cost, however, associated with the known options of wheel tuned absorbers or web shields and it was estimated that these could vary between 140 and 1100 EURO per wheel. This should be compared to a wheel cost of approximately 560 EURO.

These additional components will require increased inspection for maintenance purposes with an associated increased cost throughout their life.

The overall costs need to be compared with the costs of noise barriers and sound insulation. Current studies assume the following:

2m high barrier	810 EURO/m (single side)
3m high barrier	1080 EURO/m (single side)

4m high barrier	1350 EURO/m (single side)
sound insulation	8000 EURO per house

In the ODS main report the following values are communicated; they could not been verified in detail by the authors of present report.

Parameter, brake blocks	Costs per 4-axle vehicle, EUR	Reference	Effect, whole network
Cast iron	88 ..136	[8-3]	Baseline
k-blocks	232	[8-3]	-5 .. -8 dB(A)

Table 8-1. Investment cost and effect estimation for replacement of cast iron brake blocks with k-blocks.

Parameter, brake type or wheel dampers	Costs per 4-axle vehicle, EUR	Reference	Effect, whole network
8 ORE 920 wheels	4,480	[8-1], [8-2]	-
Block brake, conventional	12,500	[8-3]	Baseline
Drum brake	16,500	[8-3]	-10 .. -12 dB(A)
Disc brake	26,000	[8-3]	-10 .. -12 dB(A)
Wheel disc brake	20,000	[8-3]	-10 .. -12 dB(A)
Composite brake blocks	Cost neutral *)	[8-1],[8-2]	-5 .. -8 dB(A)
k-block retrofit incl. Braking system change	732	[8-3]	-5 .. -8 dB(A)
Retrofit with k-blocks and BA004 wheel sets	9,000	[8-4]	-5 .. -8 dB(A)
Wheel damping ring	800 .. 2,200	[8-3]	about -1 dB(A)
Wheel damper (ICE 1 type)	3,200 .. 4,000	[8-3]	-2 .. -4 dB(A)

*) Requires additional maintenance costs for rail grinding according to reference.

The STAIRRS project is currently reviewing comparative costs of different mitigation options taking into account:

- Initial cost
- Time period of programme implementation
- Maintenance and repair costs
- Life of a measure

There is no reason to doubt that the results will confirm conclusions from previous studies that low noise components are viable alternatives to noise barriers and sound insulation. Although it is unlikely that sufficient noise reduction at source will be achieved in the short to medium term to eliminate the need for barriers and insulation completely and still meet environmental noise reception targets with a commercially competitive railway.

6. Conclusion

A review of existing noise creation levels for conventional and high speed trains throughout Europe is presented, along with a comparison of reference values used in legislation. These values show consistency between different types of rolling stock.

A review of potential achievable reductions was carried out. However, at present, the available measurement methods are not sufficiently developed to allow the definition of a reference noise creation level for existing rolling stock. The methods presently available allow for variations of up to 10 dB depending on the actual track conditions during the measurement, and the indicator used(especially L_{Amax}). This leads to uncertainty in the levels presently achieved by existing rolling stock as well as uncertainty in the achievability of limits to be set for new rolling stock. Therefore, as a first important step, the range of uncertainty in the measurement method should be reduced to appr. ±2 dB as a maximum, through robust acoustic indicators and tighter track specification. The specification for roughness and track vibration decay rates is presented.

As far as the target values recommended by the Commission for high speed, and especially the 2005 objective, are concerned, it should be noted that the values are theoretical and correspond to research objectives. Industrial development will only lead to practical solutions after 2005. A target of 2010 seems more realistic.

Concerning the example case developed in ODS report for high speed, much progress has already been achieved through the wheel absorbers. Although research results showed a potential 3dB(A) noise reduction for aerodynamic noise from the lower part of the train, these results have not been obtained with the experiments carried out so far.

Further progress involving skirts for aerodynamic noise (high speed case) has other system implications involving safety aspects (axle boxes and wheelset temperature) which will require careful study.

These factors point to the following conclusions:

- Short term objectives should take into account the performance of existing trains.
- The 2010 target should be less demanding than the values suggested by the Commission

Both objectives should take into account implementation costs.

These conclusions apply equally to conventional speed vehicles.

Proposals for noise creation limits for high speed and conventional traffic have been presented based on data set out in the report. Lower noise levels will only be possible with the introduction of low noise components; which will need reflections on costs and benefits of the additional noise reduction. The prototypes tested to date indicate that purpose designed tuned absorbers may be effective in reducing noise levels on their own because in the majority of cases track noise dominates. Their use also makes low noise wheel mitigation options such as wheel tuned absorbers more effective.

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Appendix 1: Technical/Strategic items to be addressed

1. Introduction

First, agreement should be reached on what relationship limit values should have to real life. One important criticism toward the type approval limits for road vehicles in the European Union is that the limit values and the method by which compliance is checked, are not representative of the normal operating conditions. As a consequence, limit values have been reduced several times on a periodic basis, without much noticeable effect to the noise creation by traffic flows. One reason is that the type approval test is dominated by engine noise, whereas in normal operation tyre road noise is mainly dominant. One other reason is that the gear/engine speed combination which is to be maintained during the type approval test is not representative for most of the engine conditions during normal traffic.

One would like to avoid a similar situation in rail traffic. So, a set of conditions can be defined for the limit values to be set. Not only do these values need to be accurate, well-defined, reproducible, mutually comparable, controllable and recognisable, but they also need to be representative of actual operational noise levels. This implies for instance, that quantities like SEL or sound power level are not considered suitable because they would result in very high numbers which are not easily recognised by the general public. It also implies that, when comparing the acoustic performance of two rail vehicles where one shows lower type approval values than the other, we would prefer that this one vehicle is indeed recognised in normal operation by the general public as the quieter one. This should be kept in mind when defining limit values, quantities in which to express them and methods by which compliance should be checked.

It was underlined and agreed that in order to ensure a better reproducibility of pass-by measurements, the track should be specified more precisely. The reason for this concern is that the roughness of the track is an important parameter for the resulting acoustic performance. In the hypothetical case of ideally smooth wheels, 3 dB difference in track roughness would automatically result in 3 dB difference in generated rolling noise. Therefore, if one would want to achieve a measuring accuracy of ±1 dB, the track roughness would have to be defined within that same accuracy over the full frequency range.

Thus the following points will be discussed:

- conversion potential of results from one track to another, the track types and roughness being potentially different on different railways,
- track type specification,
- roughness specification.

2. Track specification

2.1. Standard track versus different track and conversion factors

In principle, the track specification could be starting from the following options:

1. It is left to the supplier to decide where (i.e. on which track) to carry out the compliance test. In this case the supplier would seek (or construct) the track type where the product would perform best. There would be some competition between suppliers to develop or discover the “quietest” track, which might help technological advancement. Results from different test tracks cannot easily be compared. The result of the test would not be representative for normal operation and could not be corrected to predict the performance under normal operation,

This option is for the moment not retained.

2. Alternatively a standard track type is defined, which will have to comply with a set of very tightly defined specifications. Every supplier can select or build his own test track, but it would have to comply with these specs. Now the results of different test tracks can be compared. The results would not necessarily be representative for normal operation, but, because the test track is very well defined, it would in principle be feasible to use calculated corrections to predict the behaviour on any track different from the test track.

This option is for the moment favoured in the CEN Pr EN 3095 standard.

3. Another option is for the track influence is removed from the measurement result, i.e. the track is no longer a parameter in the test result. This approach requires the collection of additional data during the measurement. This additional data set then allows correction of the measurement result so that the track influence is nil. Comparison between different vehicles is very straightforward. Predictions for actual operation can be made using calculated corrections. However, it is questionable whether research will succeed in defining this method.

Approach 2 is the approach which is followed in the prEN 3095 standard. However, the definition of track roughness needs further discussion. Approach 3 is the approach which is followed in the STAIRRS project. Approach 1 for the moment is rejected.

2.2. Track type

At present unfortunately no precise knowledge of mean value or spread of track stiffness is available, although values ranging from 80 MN /m to 1300 MN/m have been measured during various projects.

When the track is being specified, different options may be considered:

the first one consists of specifying track components which are known to reduce track noise: one might consider very stiff rail pads(>800 MN/m), bibloc sleepers etc. This approach could even lead to equipping the track with absorbers. Although this approach seemed to be followed by WG6, their proposal limited itself to pads stiffer than 500M/m, and to mono-bloc sleepers. The justification for such a choice, apart from it being easily found on some railways, is not evident. It could even be seen by the railways that do not use these components as a discriminatory measure.

For this reason, it seems much more preferable to specify the track by its dynamic properties: track vertical and lateral accelerances and track decay rates (vertical and lateral), provided it can be proven that these characteristics can be realised in practice for common track types. This would leave the choice to various member states of the components to achieve a given performance in terms of dynamic properties of track.

The following proposal can be made:

Rather than a component specification of track, a functional specification of the track characteristics is preferred, which allows the choice of the measurement site independent from the technology used at national level.

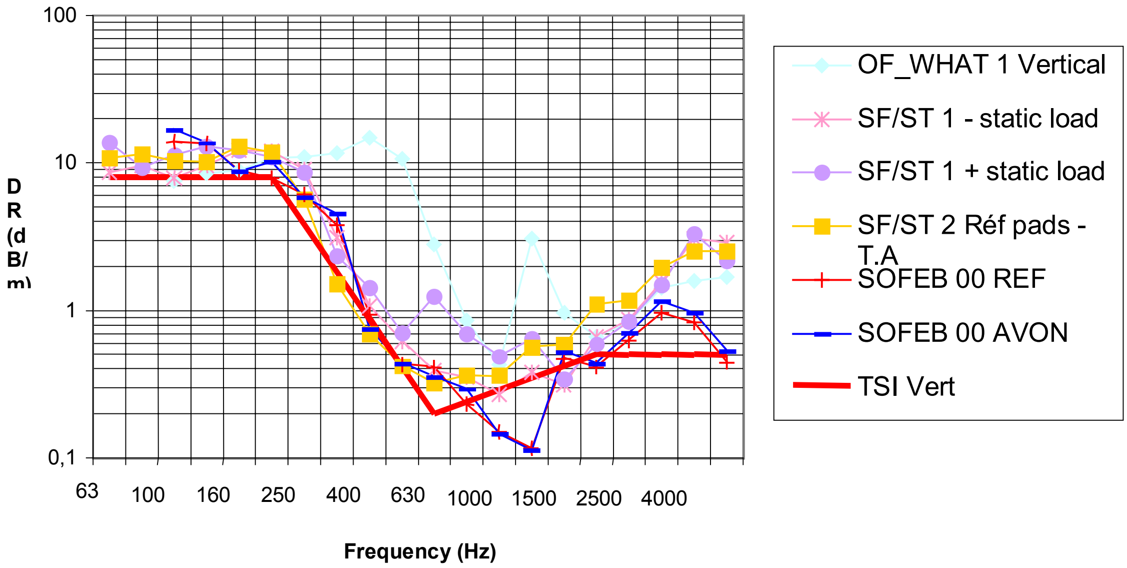
This definition has to be complemented by specifying track decay rates of vibration along track.

A proposal for track decay rates can be made from a selection of various decay rates measured on various tracks in Europe measured in the frame of different projects.

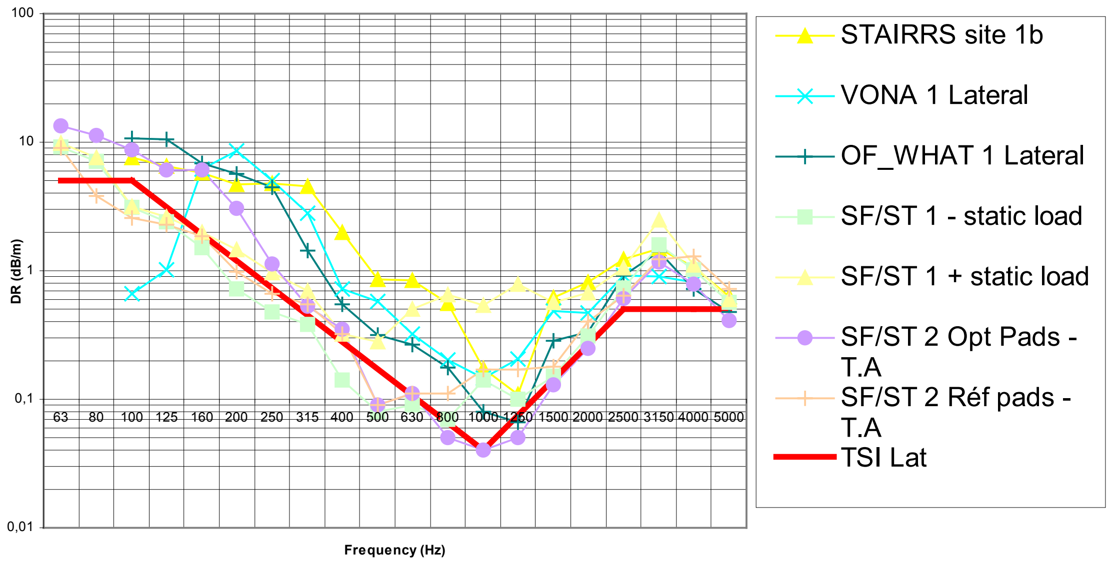
Tracks selected were not fitted with track absorbers, therefore they correspond to operational tracks.

The following proposal can be made for vertical decay rates:

Interoperable vehicles have to perform in the same way in Europe and the benefit of measures such as wheel absorbers should be seen not only a test track.



The following proposal can be made for lateral decay rates:



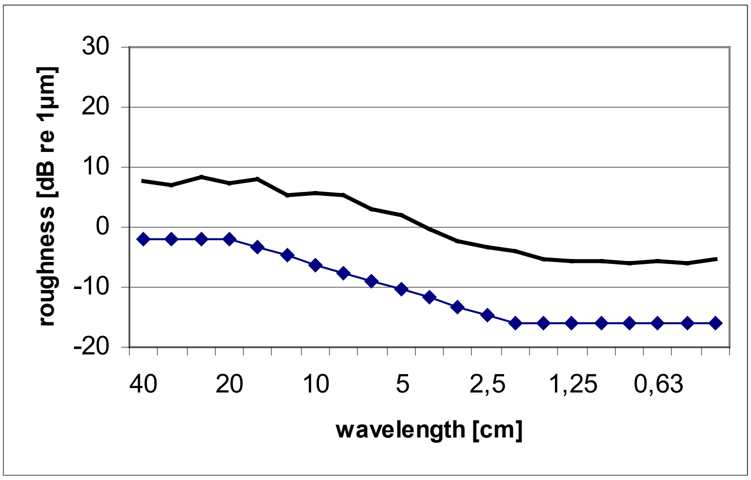
2.3. Roughness

As discussed in the previous section, the roughness of the track is a most dominant factor for the generation of rolling noise. Whenever rolling noise is the dominant noise generating mechanism (which is the case in all conventional speed rolling stock), total roughness is the energy sum of wheel and track roughness. In the hypothetical case of ideally smooth wheels, 3 dB difference in track roughness would immediately result into 3 dB difference in created rolling noise.

Given the condition stated above, that the type approval test result should be representative of normal operation, the ideal situation would be that the test track represents the typical, exact, average rail roughness as found on the network(s) where the rail vehicle will be operated. The question then arises how such a strictly defined typical roughness could be achieved and maintained. In principle, it is conceivable that a pair of special test rails could be produced, with a given inherent roughness, which is sufficiently treated so as to guarantee that this roughness will last for a long period of time. However, further research is required into the typical roughness and the methods to produce such a rail. This will not be a feasible method for the short term.

Alternatively, a low roughness level can be defined. The obvious disadvantage then is that the result of the type test will no longer be representative of real operation. In practice, a low level of roughness is maintained by checking the roughness on a regular basis and grinding the rail whenever the roughness is found to be in excess of the specified value. This is the approach that was chosen for prEN 3095. As was made clear above, grinding the rail to a roughness level which is more than marginally below the specified limit roughness would grant the supplier an unjustified advantage. So far there is no evidence that grinding techniques or procedures are available by which the rail could be ground to an exact roughness level (including wavelength spectrum). So basically this approach is as insecure as the method discussed previously.

In order to minimise the influence of the rail roughness, it would have to be reduced to a level which is negligible (i.e. 10 dB lower in all relevant wavelength bands) compared to the average roughness level of a smooth, disc braked wheel. In this case that roughness level could be maintained as an upper limit. Further smoothing of the rail would not lead to lower rolling noise levels. The figure below indicates the roughness spectrum of a very smooth, disk braked wheel, compared to the proposed limit value of the track to be included in prEN 3095.

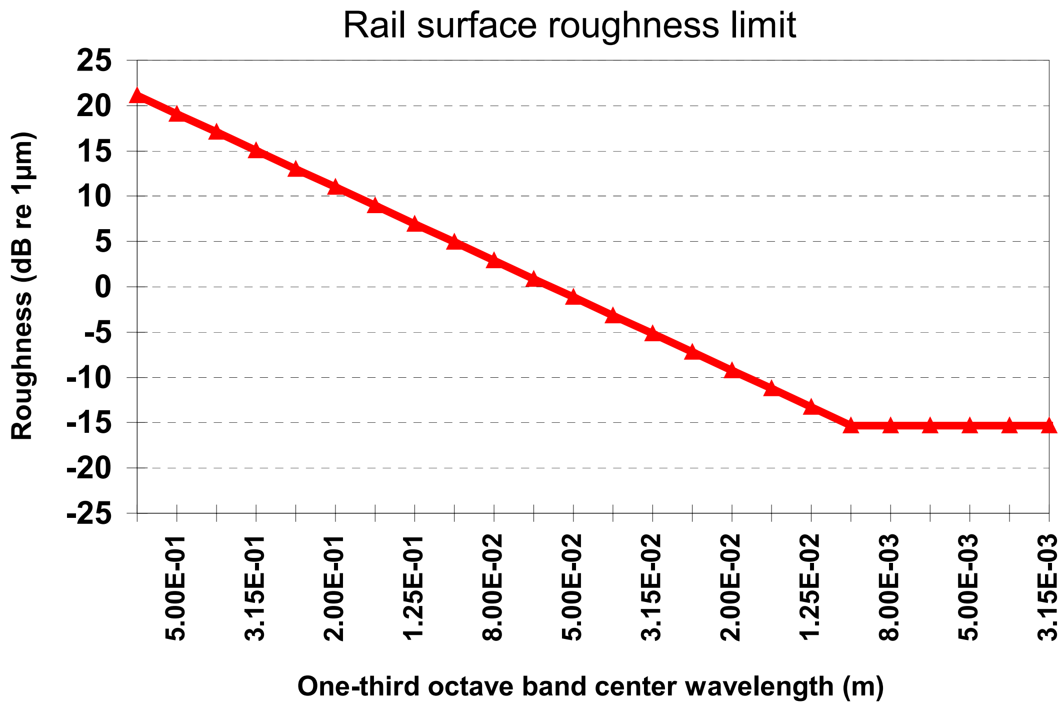


An alternative rail roughness limit has been proposed by France based on the following comments.

The range of the TSI limit curve for roughness does not take into account wavelength >0.2 m, which are important wavelengths for noise creation at high speed.

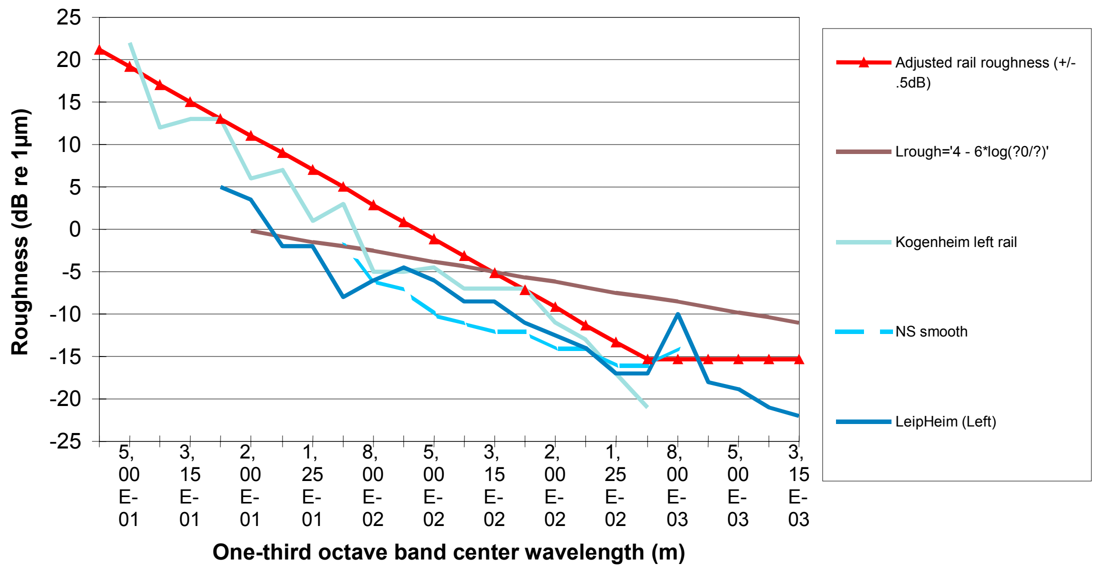
Data obtained from several countries in Europe from best conditions of rail surface do not comply with some parts of the proposed limit curve, which does not guarantee sufficient reproducibility of measurements for wavelength <0, 013m.

Therefore, the following curve is suggested (approx. 5 dB tighter than the existing one in PrEN ISO 3095), which guarantee a reproducibility of the measured noise emitted values versus rail roughness lower than ±0,5 dB (A), for current types of wheel and track.



TSI high SPEED proposal (France)

In comparison with actual data it can be seen from the following curves that:
The new proposal is tight enough to ensure a reproducibility of the rolling noise with respect to roughness within 1dB(A), while being potentially met in several locations in Europe, including TWINS validation test sites in Germany, Switzerland, High speed line sites in France, and NS typical smooth track.



The same specification is recommended for conventional speed sites

A potential problem which may be discussed: having a device reliable for track roughness measurement is presently owned only by a few companies in Europe, whereas measurement of roughness, without prescribing the device is included in Pr EN 3095 At least a few measuring devices suitable for EN3095 should be on the market.

2.4. Low noise track versus operational conditions track

In the course of trying to specify better the track properties, specifications leading to “lowest reasonable values” of the track contribution have been sought. This followed the argument that, further to ensuring the reproducibility of the measurements, the more accurate characterisation of the train noise would be carried out on a low emission track (both in terms of roughness, and dynamic properties).

Care must be taken however that:

- such a track could be easily installed in several locations, not to create monopolistic situations,
- it could be maintained without too much effort and cost,

in case it is not representative of real operational condition (both in roughness, and track dynamic properties), the results will need at least systematic correction to be representative of real situations (for impact studies for example), which is not in line with the current practice. A further test on operational test track may even be required.

2.5. Conclusion

It is therefore highly recommended, that before results from STAIRRS have demonstrated the feasibility and validation of a procedure to translate the results from one track type to another, a track functional specification, representative of “silent” but operational situations is used.

3. Vehicle/track contribution assessment

In the STAIRRS project, one of the main objectives is to develop Methodologies for the Characterisation and Categorisation of railbound vehicles and track. This objective is treated in work package 2.

In this work package one of the lines of investigation has been to look into ways to separate the contributions of vehicle and track when measuring the noise of a vehicle passing by.

One approach is to consider the pass by noise level as a result of 4 different contributing phenomena:

- the roughness spectrum of the wheel(s),
- the roughness spectrum of the rail,
- the dynamic response of the wheel(s),
- the dynamic response of the track.

This is what is defined in STAIRRS workpackage 2 as a level-2 source separation. It is assumed in STAIRRS that the dynamic responses can be described in terms of the noise by each of the two subsystems, provided that the roughnesses are known.

This is obviously one step further than the present prEN 3095, but it would allow the results of a measurement on any track to be translated into the predicted results

It is also one step further than presently needed by the TSI for assessing the effectiveness of noise mitigation options.

4. Potential limitation of track contribution

As the question of noise limitation from railways was raised, and as it was recognised that railway noise is created by a system (train+track), especially for conventional speeds, the question of the object of the limitation arises.

Limits could be theoretically put:

either on the total noise emitted by the system (train+track):as a matter of fact*, total noise is the only indicator used in practice up to now*, and current specifications put by railways in terms of national or international projects are relevant to the system (train+track). It should be highlighted that this sort of limit leaves the choice of the mix of measures that enable to reach a given objective: combination of measures on the vehicles and on the track ,which may be the only realistic technical solution to reach ambitious objectives,

or on noise emitted by *each of its components: contribution of the vehicle, and contribution of the track*. Assessing the contribution of each component from global noise and vibration measurements (and possibly calculation) is still a research issue, which is currently investigated within the STAIRRS project.

The objectives of limiting the vehicle contribution are clear. A step forward in this direction was made with the idea of specifying the track used for type test as of “low noise design” to maximise the train contribution, that is low roughness and low track contribution.

The grounds for limiting the track contribution are less clear:

as far as interoperability is concerned, as the track is a fixed element in the system, it appears for subsidiarity reasons to be the infrastructure manager’s responsibility to protect the people living by the track by whatever means he considers appropriate. In that respect, it makes no difference to the receptor if a silent track system (at source) or a noise barrier is adopted.

for the “local” situation (not concerned with interoperability), it is also for subsidiarity reasons the infrastructure manager’s responsibility to invest where he feels appropriate(track measures or barriers), once the noise from the rolling stock is minimised.

It is therefore recommended not to consider any limit on the track contribution, for the time being. This position could be reconsidered when STAIRRS results provide practically validated applications.

However, for the cases where a limitation would all the same have to be considered in the future as being of interest, the following options could be considered:

a “no corrugation case”, where a limit could be put on track roughness excluding corrugation ($r<5\mu m$ peak to peak, for example), and the track limit could be expressed in terms of roughness limitation only,

or alternatively a limit to the increase of noise on track, with respect to the standard reference track used for type-test and specified above (includes both roughness and dynamic properties, and a reference (interoperable?) vehicle.

Appendix 2: Noise creation levels from different countries

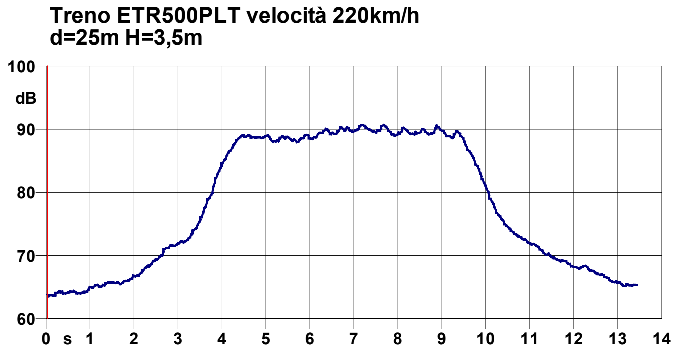
France

Materiel	Particularités freinage	V (km/h)	Niveau de Bruit (dBA)	Site de mesure
TGV Eurostar TGVR TGVA PSE modifié	Disques sur BP et semelles composites sur BM	300	93	LGV NE
Duplex	Disques seuls	300	89.5	LGV PSE
Automoteurs X 72500	X 73500 Semelles composites	160	85	Bourges
TER ancien		80 120	89 94	
Locomotives BB 17000	Semelles composites	120 140	86 88	Herblay
CC 72000	Semelles composites	140 160	91 93	Gretz
Sybic	Semelles frittées	120 140 160	86 88 89.5	
Banlieue MI2N	Semelles composites	90 120	77 81	La Villette
Z2N	Semelles frittées sur motrices et semelles fonte sur remorques	120	85	Villeneuve
Materiel Roulant Voyageurs (Voiture) V2N	**Disques seuls**	140 160	83 85	Louvres
Corail	Semelles fonte + disques	160	96	Tours
	Semelles composites + disques	160	Gain espéré de l'ordre de 5 dBA	Epones
Fret Fret	Semelles fonte	100 120 140 160	91 93.5 95.5 97	
Fret	Semelles composites (Trémies ballast)	100	Gain espéré de l'ordre de 5 dBA	Tours
Sernam	Semelles composites + disques	200	93	

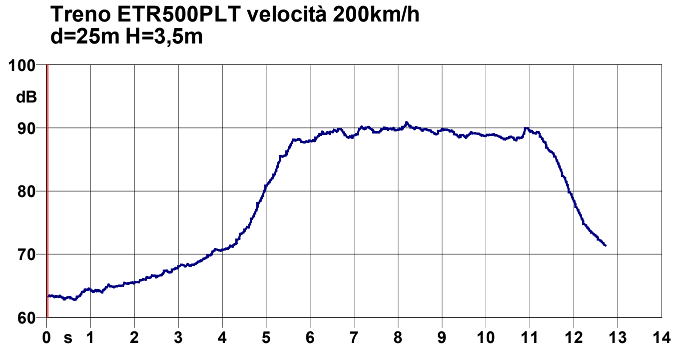
Switzerland

Vehicle Class	Type	Brake	v [km/h]	distance [m]	Lpmax [dB(A)]	source/remark
PASSENGER COACHES						
Passenger coach	EW-I/II	cast iron	80	7.5	93	I-GP LS, rep A074
Passenger coach	EW-I/II	cast iron	100	7.5	94-96	I-GP LS, rep A074
Passenger coach	EW-I/II	cast iron	125	7.5	100	I-GP LS, rep A074
Passenger coach	RIC	cast iron	80	7.5	94	rep A074
Passenger coach	EW-I	K-Bloc	80	7.5	86	I-GP LS, rep A074
Passenger coach	EW-I	K-Bloc	125	7.5	92	I-GP LS, rep A074
Passenger coach	EW-III	K-Bloc	80	7.5	86	I-GP LS, rep A074
Passenger coach	EW-IV	Disc	80	7.5	79	I-GP LS, rep A074
Passenger coach	EW-IV	Disc	125	7.5	86	I-GP LS, rep A074
Passenger coach	EW-IV	Disc	160	7.5	91-92	I-GP LS, rep A074
Passenger coach	Bpm-EC	Disc	80	7.5	80-83	rep A074
Double Decker	S Bahn	Disc	80	7.5	78	rep A074
Double Decker	IC 2000	Disc	80	7.5	80	rep A074
Passenger coach	RIC	Disc	80	7.5	81	rep A074
Passenger coach	Hotel pass.	Disc	80	7.5	79	rep A074
FREIGHT WAGONS						
Freight Wagon	RLS	Disc	80	7.5	84	rep A074
Freight Wagon	four axles	Disc	80	7.5	87	situation 96
Freight Wagon	G-G	cast iron	80	7.5	93-99	rep A074
Freight Wagon	two axles	cast iron	80	7.5	96-99	situation 96
Freight Wagon	four axles	cast iron	80	7.5	95-100	situation 96
Freight Wagon	G-K	K-bloc	80	7.5	84-88	test train 1999
Freight Wagon	G-K	K-bloc	80	7.5	80-84	test train 2000
LOCOMOTIVES AND EMUs						
Locomotive	Re4/4-II	cast iron	80	7.5	90-91	I-GP LS, rep A074
Locomotive	Re460/450	Disc, sinter bloc	80	7.5	81-82	I-GP LS, rep A074
Locomotive	Re460 ("Lok 2000")	Disc, sinter bloc	80	7.5	81	rep A074
Locomotive	Ae 6/6	cast iron	80	7.5	90	rep A074
Locomotive	Re 4/4 I	cast iron	80	7.5	89	situation 96
Locomotive	Re 6/6	cast iron	80	7.5	91	rep A074
EMU	NPZ Bt	K-bloc	80	7.5	88	I-GP LS
EMU	NPZ	Disc	80	7.5	80	rep A074
EMU	RABDe 12/12	K-Bloc	80	7.5	87	rep A074
EMU	RABDe 8/16	Disc, cast iron	80	7.5	93	rep A074
EMU	RBDe 4/4 (NPZ)	Disc, cast iron	80	7.5	88	rep A074
EMU	RBe 4/4	cast iron	80	7.5	97	rep A074

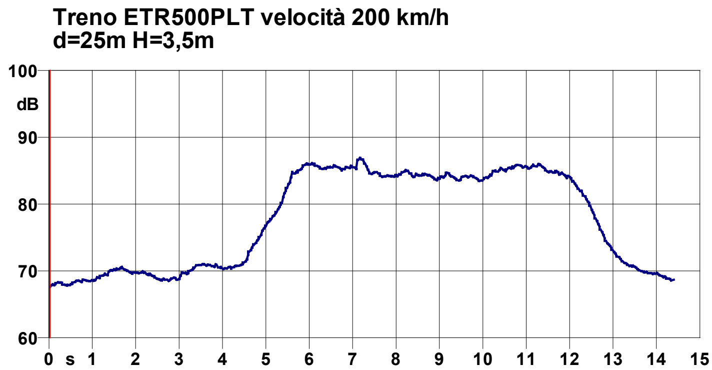
Italy



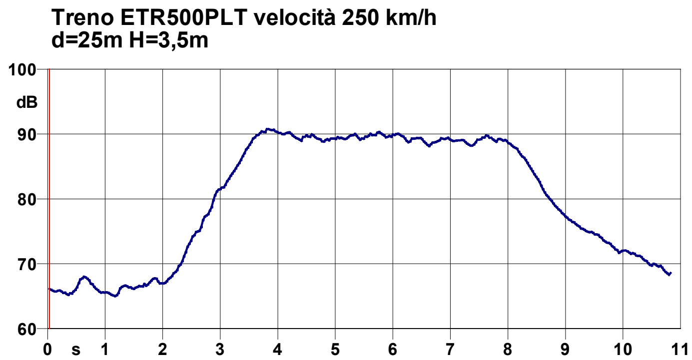
L_{pAeq} = 88.3 TEL= 89.3 L_{max}= 90.7



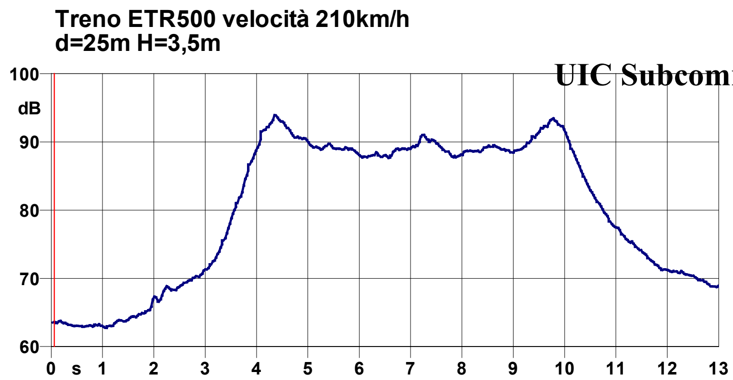
L_{pAeq} = 88.1 TEL= 89.1 L_{max}= 90.8



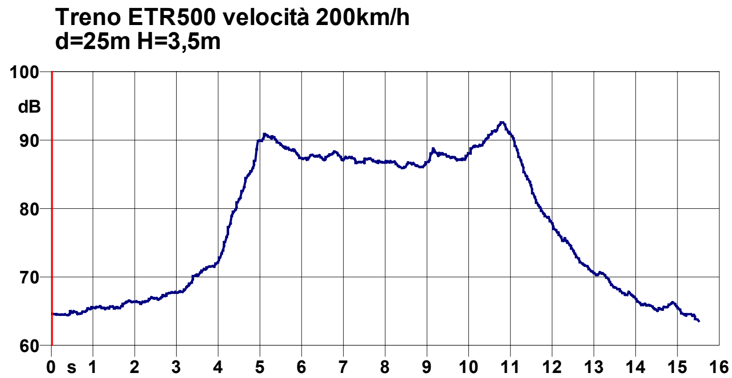
L_{pAeq} = 84.6 TEL= 85.1 L_{max}= 86.9



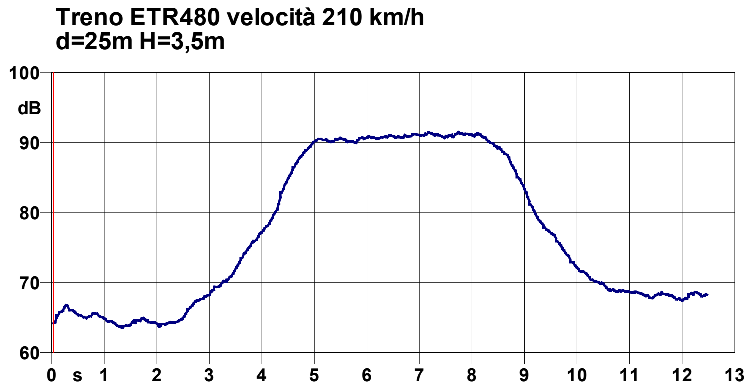
L_{pAeq} = 88.3 TEL= 89.7 L_{max}= 90.8



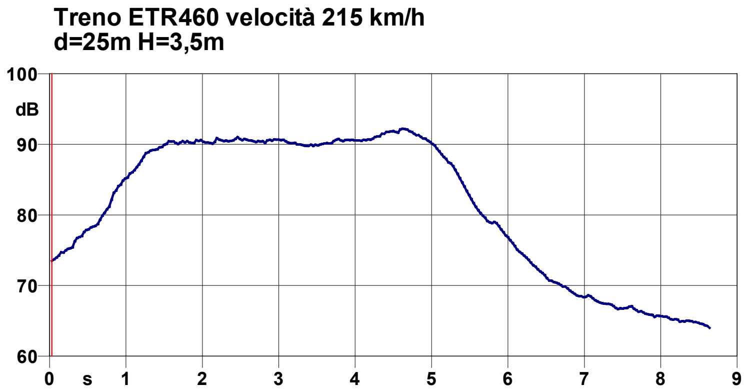
$L_{pAeq} = 89.0$ TEL= 90.6 $L_{max}= 93.9$



$L_{pAeq} = 87.6$ TEL= 89.0 $L_{max}= 92.6$

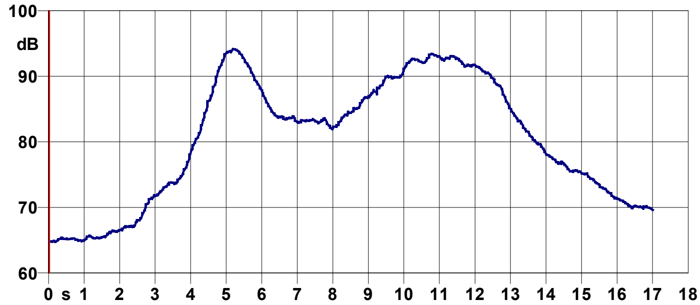


$L_{pAeq} = 89.4$ TEL= 90.7 $L_{max}= 91.5$



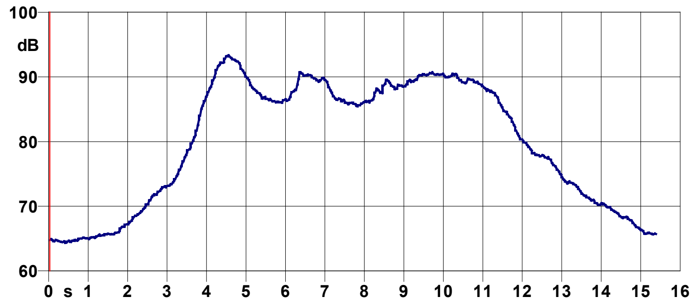
$L_{pAeq} = 89.0$ TEL= 90.8 $L_{max}= 92.2$

Treno IC -Loc. E.402A- velocità 200 km/h
d=25m H=3,5m



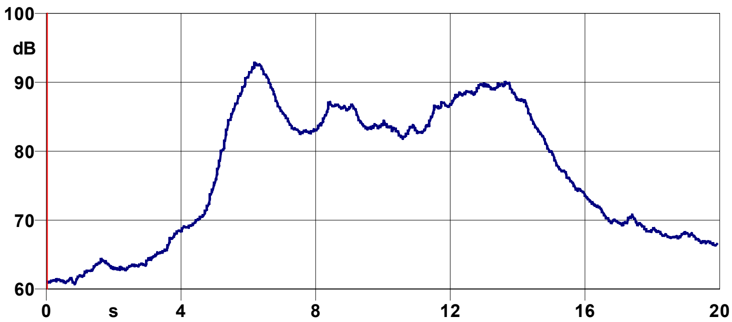
L_{pAeq} = 88.8 **TEL= 90.6** **L_{max}= 94.2**

Treno IC- Loc. E.402A velocità 195 km/h
d=25m H=3,5m



L_{pAeq} = 88.2 **TEL= 89.7** **L_{max}= 93.3**

Treno IC- Loc. E.656 velocità 150 km/h
d=25m H=3,5m



L_{pAeq} = 86.4 **TEL= 87,8** **L_{max}= 92.8**

Valori rilevati da Prove di Tipo (d=25m H=3,5m)

Locomotiva E464
v=160 km/h L_{max} 87.5
v= 80 km/h Lmax 82.0

TAF
v=140 km/h Lmax 88.5
v= 80 km/h L_{max} 77.3

Germany

All Values 25m from Track	ODS-Main Report Okt.01	ODS	UBA (German	TSI 7.4.2	Measured Values TEL (80) by DB AG on very smooth track	~number of vehicles
Type of Vehicles	Table 9.5	after service	environm. Authority)	(Version11, 16.10.01)	Modern Vehicles	that type at DB AG
Locomotives (<250 km/h) (newest technologies, step1) (step 2, "5 years")	73 (Lok"2000") 71	+3 +3	73 69	- -	E 145: 77 (wheel-disc-brakes) E 152: 79 ("' " ")	90 170
Electrical multiple Units (EMU) (< 250 km/h) Step 1 Step 2	 73 (DSB S-B.) 71	 +4 +4	 71 67	 - -	ET 423: 74 (wheel-disc-brakes) ET 474: 72 (" " ") ET 411: 75 (disc or wheel-d.-b., tilting)	230 + 30 + 43
Passenger-Coaches step 1 (ODS is ranking hereunder ICE 1, too!) step 2	68 (retrofit 73) 65	(+3 ?) (+3 ?)	68 66	- -	76 is standard value for disc-braked vehicles without cleaning-blocks ~71 Coaches of ICE 1	~ 12000 ~ 800
Goods-Wagons step 1 Step 2	74(retrofit 78, f.e. ÖBB-Sgjss) (72 (KTLG)) 70	+5 +5	73 68	- -	86 is standard value für cast-iron-bloc-braked wagons 77 with K-bloc-brakes 75 with disc-brakes	~120000 ~500 + ~300
	Table 9.4				TEL (250)	
Trainsets (> 250 km/h) step 1 Step 2	250 km/h: 87 85 350 km/h: 91	+3 +3	85 82	87 350 km/h:94* 85 350 km/h: 91	ICE 1+2: 87	104
High-Speed-Traffic (HST)-EMU (>250 km/h) Step1 Step 2	as Trainsets	"	86 330km/h 91 82 330km/h 87	as Trainsets	ICE 3, 330 km/h: 94,5 (axle-d.-br.with absorbers or wheel-d.-br. without absorbers)	54

The Netherlands

Kategory	Description	Emission number														
		a	b	Q	C	v	E	d	DeltaL(d)	DeltaL (air)	B	DeltaL (ground)	DeltaL (meteo)	LAeq	Length	**Tpassage**	LAeq, passage
1	CI tread braked Intercity EMU " Mat 64"	14,9	23,6	6,0	0,0	80,0	67,6	25,0	14,0	0,3	1	0,9	0,0	52,5	150,0	10,13	78,0
2	CI tread braked Intercity Coaches, Double Decker Coaches and ICM EMU's	18,8	22,3	6,0	0,0	80,0	69,0	25,0	14,0	0,3	1	0,9	0,0	53,9	156,0	10,40	79,3
3	Disk braked Regional SGM	20,5	19,6	4,0	0,0	80,0	63,8	25,0	14,0	0,3	1	0,9	0,0	48,7	104,0	8,06	75,2
4	Freight (CI tread braked)	24,3	20,0	30,0	0,0	80,0	77,1	25,0	14,0	0,3	1	0,9	0,0	62,0	375,0	20,25	84,5
5	Diesel-Electrical EMU	46,0	10,0	2,0	0,0	80,0	68,0	25,0	14,0	0,3	1	0,9	0,0	52,9	52,0	5,72	80,9
6	Diesel-Hydraulic EMU	20,5	19,6	2,0	0,0	80,0	60,8	25,0	14,0	0,3	1	0,9	0,0	45,7	44,0	5,36	74,0
7	tram and metro	18,0	22,0	3,0	0,0	80,0	64,6	25,0	14,0	0,3	1	0,9	0,0	49,5	50,0	5,63	77,6
8	Disk braked and composite braked Double decker coaches, ICM EMU's and Regional EMU's	25,7	16,1	4,0	0,0	80,0	62,4	25,0	14,0	0,3	1	0,9	0,0	47,2	102,0	7,97	73,8
9	Thalys	22,0	18,3	10,0	0,0	80,0	66,8	25,0	14,0	0,3	1	0,9	0,0	51,7	224,0	13,46	76,0

*For high speed 25 m is preferred : such speeds are only archived on purpose bolt new infrastructure which normally incorporates noise barriers. Houses are never forest as close as 7.5 m to stretch new railways.

Appendix 3:Comment of UIC towards the System Cases mentioned in the report: A Study of European Priorities and Strategies for Railway Noise Abatement (ODS, Oct 2001)

Introduction

So called "Best practice cases" in railway noise creation were put together by the consortium Odegaard & Danneskiold-Samsoe A/S in the annex 2 of their report, which is serving as the basis for the EC for proposals on noise creation currently under discussion for the TSI noise. Such an approach is very ambitious since railway noise is the interaction of both vehicle and track. At the moment, validated separation methods have not yet been developed. Thus, the national infrastructures play a key role in the noise creation of vehicles. The study of best cases of railway vehicle technology therefore has limited use in setting targets for general noise creation levels, as the noise levels remain always dependent on the infrastructure they have been designed for.

This annex presents a table giving an overview concerning the different noise reduction options concerning track and vehicle noise presented in the annex 2 of the ODS report as well as the comment of UIC towards the presented best cases and indications concerning present technologies applied in the railway world.

ODS Annex II	ODS Final report	Technology	Best practice case in ODS reports	Comments UIC	Current used technology	Other comments
4	-	Track design	Grinding technologies with abrasion parallel to the rail („Rutschersteine“)	Technology not largely available.	Low rail roughness with improved rail grinding and maintenance SILENT TRACK Result: Tuned rail absorbers are the most effective design for low-noise track for conventional rail. It was shown that their effect is independent of pad stiffness, thus low stiffness pads, required by the infrastructure engineer, can be used in low noise designs incorporating rail tuned absorbers.	Due to the wheel-rail interactions, different effects in track noise reduction cannot be added to each other, but for each effect the noise reduction has to be calculated again (e.g. with TWINS simulation). It is important to note that measures on track will be more significant for noise reduction, if the wheels of the trains are smooth (K-bloc or disc braked). Another obvious limitation is that track measures have only local effect.
			Acoustically optimised pad stiffness	The use of high stiffness rail pads to reduce noise, with other parameters equal, is recognised and was investigated in the Silent Track project. There are however adverse consequence associated with their use such as high impact loads on the sleepers causing damage and a higher roughness level on the rail which will lead to higher noise levels. For these reasons infrastructure engineers do not favour high stiffness rail pads for operational tracks.		
			Low noise track developed with the project Stiller Trainverkeer (rail profile SA 42)	The low-noise track design of the Dutch project “Stiller Treinverkeer” did not prove applicable for engineering purposes. This was also the special case of a project incorporating a slab track design and to date the use of slab tracks gives rise to greatly increased noise levels.		
7	12.3	Design of EMUs, Copen-hagen S-Train 4th generation cars	Copenhagen 4th generation S-Train	The high axle load of 20-22t in comparison to normal axle load of 12-13 t makes out of the case a single case, as on most networks high axle loads are not preferred for passenger traffic on the existing infrastructure.	Crusaris Regina EMU with cheek-mounted disc-brakes: TEL of 82 dB(A) (180 km/h @ 25 m). This corresponds to TEL of 78 dB(A) (80 km/h @ 7.5m). The measurements were taken on a newly ground track with a very low roughness level.	Emission levels of 80 dB(A) at 80 km/h and 7.5m seem to be the level which is possible to reach on average track. How to achieve a further 2 dB with average rail roughness as postulated in the ODS report is not clear yet.

ODS Annex II	ODS Final report	Technology	Best practice case in ODS reports	Comments UIC	Current used technology	Other comments
-	-	DMU	No cases indicated, however recommended emission levels in the main report mentioned	ODS provides no data on Diesel Multiple Units. However, in the main report limit values with unclear origin are proposed.		The lack of data concerning DMUs is problematic since Diesel engines form an important part of the fleet. Rolling noise only dominates at higher speeds on level track and the same mitigation measures as for electric trains will be effective at these speeds.
8	12.4	Design of high-speed trains (HST)	Virtual High Speed Train	Each system of a High-Speed train set is a development of one closed system. The virtual high speed train, composed of the components of all different systems of high speed trains with the best noise-reduction performance, cannot exist in reality. It is not possible to start with one design and then apply the sound reduction measures of the other design.	**X2000**: The trainset was measured '93 on a new track with 1 locomotive and 6 coaches: TEL of 94dB(A) (260km/h @ 25m). This is 6.5dB higher than the new limit in the TSI for high-speed. '98 the Oslo Airport Express Train was tested on different tracks. In Sweden a TEL of 86dB(A) at 200 km/h was measured whereas TEL of 90dB(A) was measured in Norway with the same trainset. **TGV Duplex**: TEL 90dB(A) (300km/h @ 25m)	The effect of measures to reduce rolling noise are known to a rather high accuracy +/- 1 dB The effect of measures to reduce aero acoustic noise is well known in European railway industry There are technical solutions predicted to reach the TSI levels but they have not yet been implemented in any running train (c.f. "Noise reduction scenarios for compliance with future noise legislation" by Siv Leth, 7th IRWN, 2001)

ODS Annex II	ODS Final report	Technology	Best practice case in ODS reports	Comments UIC	Current used technology	Other comments
			Jakobs Bogie as noise reduction measure	The comparison of trains with normal bogies and with Jakobs-bogie is difficult: Fewer wheels will give lower noise levels, but the train must have a minimum number of wheels to support the load. Designs incorporating articulated bogies (Jakobs) between vehicle connections must consequently use shorter vehicles for a given train length. The noise benefit is therefore a function of the reduced number of wheels per train length. Engineering design practice indicates that a reduction in the number of wheels to reduce the noise by 2.5 dB(A) almost half the wheels on the train) is not practicable. It is also not possible to introduce such bogies into the power car design.		The cited figures of High speed train sets, 25m on page 22 of the main report, Table 5-1 are not proven in the case study retrieval report. The respective figures are quoted on p. 59, table 8-5 of the case study retrieval report, and differ between 0.5 and 3 dB, respectively there are no data presented in the case study retrieval report at all.
			Single-ring, rubber-sprung wheel	This wheel was the cause of the accident of Eschede in 1998 and cannot be seen as a technically reliable measure		
			Pantograph design(Japanese results)	Japanese results for noise reduction cannot be used for European pantographs, as the vehicle clearance profiles of Europe and Japan differs. Also, Japanese results tend to reflect a situation with elevated track and level receiver, where elevated sources are of higher importance.		
			Wheel dampers	Noise reduction of power-car trains cannot be transferred to coaches: Wheel dampers are possible only for power cars. Other cars already have damped wheels, and additional wheel dampers are impossible.		

ODS Annex II	ODS Final report	Technology	Best practice case According to ODS reports	Comments UIC	Current used technology	Other comments
9.	Non existent	Design of passenger coaches	Add tuned absorbers	For state of the art passenger coaches the wheels are already optimised acoustically and therefore one cannot add any improvement except for axle mounted brake discs, where additional damping is possible. The main difficulty is that tuned absorbers will only work on their own if the wheel is the dominant noise source and that appears to be rarely the case in general.	The present commonly used design is a 4 axle disc braked coach . For the overall noise reduction, double-deckers have the best performance (in terms of emissions per transported person, respectively for train length)	Calculating actual noise levels from passenger coaches out of values from acoustical characteristics of ICE1, as done by ODS, is problematic. Exact data for passenger coaches is missing in the ODS report, and limit values are derived from calculations which are based on one model, where basic data is omitted. Comparing actual values for international passenger vehicles with the ones from freight vehicles shows clearly, that the freight vehicle noise is dominant. It is questionable whether it is in this situation effective to reduce passenger coach noise.
			Bogie skirts/shrouds	Screens on the vehicle have been shown to give an improvement of up to 7 dB when used in conjunction with low trackside barriers. This improvement can be gained only if the barrier and shroud overlap. International gauge envelopes indicate that this overlap cannot be achieved for international trains unless the trackside barrier is a conventional , high barrier design. The benefit of a bogie shroud/low barrier combination may therefore only provide a few dB benefit for train designs approved for International traffic. At the moment, bogie shrouds are not available on the market.		
			Jakobs-bogies (SNCF)	The noise reduction of Jakobs-bogies is 1.5dB(A). The effect is not 100%, as the train length for wagons with Jakobs bogies is smaller. Noise emissions of TEL = 75 dB(A) are only achievable with additional track damping		
10	12.5	Design of locomotives	Lok2000	The Lok2000 is, due to the merging processes in the railway industry, no longer on the market.	Disc braked locomotive like the locomotive for DB/Railion (BR185), SBB Cargo (RE482).	
-	-	Design of Diesel locomotives		No case study presented, however diesel locomotives form an important part of the European fleet	Heavy freight locomotives Noise optimised, disc braked Rh 2016 (ÖBB)	Diesel locomotive have the same acoustic performance as electric at cruising speed, but during acceleration/ under full load there is a disadvantage.

ODS Annex II	ODS Final report	Technology	Best practice case in ODS reports	Comments UIC	Current used technology	Other comments
11	12.6	Freight Wagon Design	Komponententräger	Komponententräger remains for the time being a prototype and would not be acceptable for international traffic.	At the moment, there are no designs for new rolling stock promising more reduction than design with disc brakes or designs with K-blocs available.	Principal option for reduction of rolling noise from existing freight wagons: replacement of the cast iron brake blocs with composite brake blocs The development of the K-blocs and the process for the homologation was executed by the railways not due to political pressure but on a voluntary basis in order to improve the environmental performance of the freight system. Due to the long life of freight wagons the introduction of new vehicles with K-blocs and resilient wheels will take too long to have an effect on noise reduction in the short term. The costs for the replacement of K-blocs for the whole European fleet are too high for the railways. Financial support from public funds is needed. Such an investment into the vehicles will have more effect than the investment of the same amount of money into passive noise reduction measures like barriers (c.f. results of the Cost Benefit Analysis executed by the UIC 1998-1999and results of ongoing EU/UIC funded STAIRRS project). The Silent freight project showed that noise radiated by wheel can be reduced by tuned absorbers added to the wheel web or by shielding the web. For freight operation however track noise dominates and lower noise levels than can be achieved with smooth wheels and smooth rails can only be achieved when tuned absorbers are added to the rail.
			Low noise train	Results not yet available		
			Stiller Trainverkeer	For the time being a prototype not available on the market		
			K-blocs	.		