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Environmental integration of measures to reduce railway noise in the Brussels Capital Region

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Abstract

The Brussels Capital Region is a densely populated area with a surface area of 63 square miles and a total of 40 miles of railway lines. Earlier studies have already registered a large number of problems regarding railway noise. Moreover, the transport policy of the federal government aims to increase train travel and plans an expansion of the railway network. In order to be able to control railway noise, the Brussels authority needs an instrument that provides technical and practical information concerning:

- minimizing the noise produced by railways (both existing and new);
- the environmental integration of noise abatement measures.

This paper discusses the objectives of the study, the methodology that was applied, and the main conclusions reached.

1. Introduction

Belgium comprises 3 regions: the Flemish Region, the Walloon Region and the Brussels Capital Region. Every region has its own environmental laws. The Brussels Capital Region is the financial and political center of Belgium and is densely populated (1 000 000 inhabitants in a surface area of 63 square miles). Every day more than 600 000 people commute to work in Brussels, 55% of which originate from outside the Brussels Region. Consequently, public transport is an important means of transportation. At present, there are about 40 miles of railway tracks. Earlier studies have already registered a large number of problems regarding railway noise. In addition, the federal government pursues a transport policy which aims to increase travel by train. In this

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context, the railway network will be expanded (Regional Express Net: REN). In order to be able to control the noise from existing and new railway lines the Brussels Capital Region has commissioned a study with the following objectives:

1. to specify the main technical characteristics that should be considered when purchasing new rolling stock (within the scope of the REN), in order to maximize acoustic performance;
2. to develop a decision-support instrument that can assist in the design of technical solutions and that can offer practical recommendations for the environmental integration of noise barriers;
3. to establish an inventory of technical solutions (for existing rolling stock and railway tracks) that can be applied in the Brussels Region to limit the noise impact of railway traffic. Each of the solutions must be assessed in terms of its practical and economic merits.

During the study, information was combined from numerous local and international research projects. Information was also collected from manufacturers of rolling stock, noise were applied barriers, etc. In addition, numerical modelling techniques were applied. The results were tested against practical and economic criteria. The methodology and results are explained in the paper below.

2. Acoustic requirements for new rolling stock

The objective of this section is to specify the main technical characteristics that should be considered when buying new rolling stock in order to determine the acoustic performance of the vehicle.

2.1. Methodology

The study was performed in 6 steps:

Step 1 Defining and indicating the *parts* of trains that influence noise emissions (for instance, type of engine, type of brakes, type of wheel, axles (driven or not), etc. Examination of the available technologies to improve the acoustic quality of each part.

Step 2 Drafting a *classification schedule for parts influencing noise emissions*, indicating the "acoustic quality" and the relative noise contribution.

Step 3 Preparing an *inventory of rolling stock,* to include rolling stock planned for renovation, new rolling stock already purchased but not yet delivered, rolling stock planned by current investment programs, rolling stock required by REN.

Step 4 On the basis of the inventory a number of important train types was selected for examination. For each train type, the components influencing the noise emission s (see step 1) are shown in Table 1.

Step 5 Drafting an *acoustic classification scheme for the train types.*

Step 6 Drafting recommendations for the purchase of new rolling stock and the renovation of existing stock. Drafting technical specifications *concerning the acoustic performances of new rolling stock for use in tender documents.*

Table 1
Classification scheme for emission influencing components

System	Component	Type	Remark	Class		Order by relative noise contribution
Engine and aggregates	Engine (driven)	Diesel			–	(4)
		Electric	The rule with passenger trains		+	
	Ventilation	Absorption material intake and exhaust			+	
Brake system	Not on tread	Brake discs	Lack of space?		++	(1)
		Magnet brake	For emergency stop		+	
		Electro dynamical brake	Restricted brake power		+	
		Drum brake	If space, preferably brake disc		0	
	On tread	Cast iron	Wheel roughing		–	
		Sinter	Copper and chrome emission		–	
		K-block	Developed for new freight wagons	−8 dB(A)[a]	0	
		LL-block	Still in development, not yet successful			
Wheels		Reduce wheel diameter	Only for new train types		+	(2)
		Wheel shield		−1 dB(A)	0	
		Wheels with spokes or perforated wheels	Still very experimental			
		Anti Block System (even distribution of brake pressure)	Prevents flat wheel sections		+	
		Wheel damping		−4 dB(A)	+	
		Resilient wheels		−2 dB(A)	+	
		K-block + wheel damping + wheel shield		−9 dB(A)		
		Wheel maintenance (mill tread)	Wheel roughness can be controlled	−6 dB(A)	++	
Others		Absorption under wagon		−5 dB(A)	+	(3)
		Shields (over wheels) on vehicle body		−6 dB(A)	++	

[a] With respect to cast-iron brake blocks.

2.2. Main results and conclusions

2.2.1. Classification schedule for emission influencing components

On the basis of the findings from the first step it was possible to draw up a classification scheme for components on the basis of the noise creation potential. The study was restricted to passenger trains, in view of the situation in the Brussels Capital Region.

The last column in the classification scheme (see Table 1) indicates the relative importance of the system's acoustic contribution with respect to total noise production. '1' indicates the most important sources of noise, and '4' the least important.

In the penultimate column a qualitative assessment is attributed to each subsystem from '−−' for poor quality and/or to be avoided, to '++' for good quality and/or to be recommended. The reduction values expressed in dB(A) are indicative and depend on particular situations.

On the basis of the classification scheme the following conclusions can be derived for the construction of newer, more silent trains:

- Abandon use of cast iron brake blocks.
- A general use of disc brakes, also on driven bogies, in combination with electrodynamic and/or magnetic brakes.
- Acoustic silencers on locomotive and ancillaries.
- Use of smaller wheels.
- Shielding of the wheels by sound absorbing side panels mounted on the vehicle body.
- Regular maintenance of wheel tread.

2.2.2. Classification scheme for train types

On the basis of the findings from the previous steps, it was possible to derive a classification schedule for train types (see Table 2). The classification results primarily from the following considerations:

- Type 1: Acoustic output determined by rolling noise, no brakes on tread.
- Type 2: Acoustic output determined by rolling noise, disc brakes and block brakes on tread.
- Type 3: Acoustic output determined by rolling noise, block brakes only.
- Type 4: Acoustic output determined by diesel engine.
- Type 5: Acoustic output determined by rolling noise of freight wagons, block brakes only.
- Type 6: Acoustic output determined by aerodynamic noise.

2.2.3. Technical specifications regarding acoustic performances of new rolling stock

In this step, specifications were developed for new rolling stock with a view to minimize noise nuisance. First, general technical specifications of the trains were formulated, such as:

- The vehicle body is to be fitted with side panels that cover the bogies. They are to be mounted as low as allowed by the specified gauge. Near the bogies the vehicle body is to be lined with acoustic absorbing material on the inside and at the bottom.
- The ventilators must be fitted with acoustic silencers on the inlet and exhaust sides. When the train is stopped, the ventilation capacity is to be reduced to the minimum required for cooling.

Table 2
Classification scheme for train types (source: NMBS/RUG)

	Type of transport	Type of brake	Type of train	Acoustic source output $L_{w,axle,100km/h}$
Type 1	Passenger transport	No brakes on tread or with special block brakes	AM86, M5, I10, I11 as well as HST at speeds below 200 km/h and electric locomotives	103.9
Type 2	Passenger transport	Disc and block brakes on tread	AM75, AM80, AM96, M4, I6	109.0
Type 3	Passenger transport	Only block brakes	M2	107.6
Type 4	Passenger transport	Diesel engines with disc and block brake	AR41	
Type 5	Freight transport	With block brakes only		109.3
Type 6	HST	At high speed	Thalys, Eurostar	104.8 ($h = 0.25$ m) 101.2 ($h = 0.25$ m)

- Inspection measurements must be carried out upon delivery of fully finished trains. These should be manufactured in accordance with the provisions mentioned above, and must meet the imposed noise ceilings.
- Braking systems that operate on the tread of the wheel are to be banned.[1]

Secondly, the method of performing the inspection upon delivery was defined, including norms to be applied, external testing conditions, parameters to be measured ($L_{Aeq,\,100\,ms}$, L_{max}, $L_{Aeq,\,passage}$), the reference track, pass-by speed during the measurements, etc.

Until recently there were 2 different standards for type control methods for external noise from railway traffic:

- ISO 3095 "Measurement of noise emitted by railbound vehicles", 1993 (draft).
- CEN/TC256/WG3 "Measurement of external noise emitted by railbound vehicles", 1995 (draft).

In Spring 1998 a working group of CEN and ISO started preparing a final version of a single common document. The title is EN ISO 3095, the draft being prEN ISO 3095. The introduction of rail roughness measurements is the most important aspect of the draft. The main elements from the draft standard are the following:

- specifying a limit for rail roughness in the main text of the document (normative) (see Fig. 1);
- description of the measurement procedure (normative);
- description of the background to the derivation of the rail roughness limit (informative).

[1] For this recommendation there is, however, no consensus. It is technically feasible, but possibly implies the need for a larger number of driven bogies for the same installed drive capacity, resulting in a major change of the overall concept and a significant additional cost. It is generally agreed, though, that the use of cast-iron brake blocks roughens the tread of the wheel, leading to a substantial increase of the acoustic power, and therefore the potential noise nuisance.

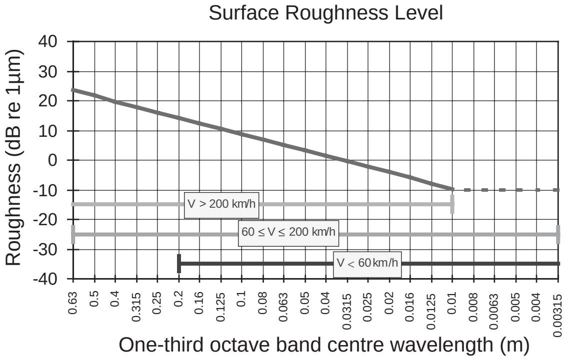

Fig. 1. Rail roughness limit in prEN ISO 3095 based on measured results on existing infrastructure and rolling stock throughout Europe that are representative of rail in good condition. Application of this rail roughness limit leads to a change in noise level of less than 4 dB(A) when combined with smooth disc braked wheels.

3. Restriction of the propagation of noise: sound barriers

Noise barriers, or screens, are the most commonly used remedy against the propagation of the railway noise. The design of these barriers usually consists of relatively high walls, with little or no attention being paid to their integration into the landscape. Local residents object to the screens because they regard the vegetation and the landscaping of the railway embankments visually more attractive than the screens. This problem has created the need for technical solutions to reduce noise propagation which pay more attention to the integration of the screens into the landscape.

3.1. Methodology

The investigation of sound screens consisted of the following steps:

Step 1 *Definition of the problem constraints*, *the assessment criteria and the different typical site configurations*. When installing or modifying noise abatement provisions, a number of constraints has to be taken into account, such as available space, safety, accessibility of the rail for maintenance, required acoustic reduction, costs, etc. These constraints can be translated into criteria for the assessment of solutions. The analyses in this study were conducted for a number of typical site configurations, which are representative of the Brussels Region regarding elevation of the track relative to its surroundings, the width of the track or the number of tracks, the height of the buildings, etc. In Step 1 an inventory was made of the typical site configurations.

Step 2 Step 2 was devoted to the determination of the *acoustic effectiveness of the various types of noise barriers under* different site configurations. This was accomplished partly by numerical model calculations and partly by the application of results from the literature.

Step 3 Development of *proposals for the integration of the different types of noise barriers in the landscape*. In this step ways were examined to improve the integration of the sound barriers considered in Step 2 into the surrounding landscape. In other words, for each solution a number of 'green' variants were designed.

Step 4 Assessment of *the solutions*: Next the solutions and variants developed in the previous steps were assessed using the evaluation criteria defined in Step 1. The analysis included results from the literature and information obtained from the National Railroad Company and from manufacturers of sound barriers.

Step 5 *Synthesis and recommendations*. The evaluation scores for all solutions and sub-variants were synthesized and presented in a summary table.

3.2. Main results and conclusions

3.2.1. Acoustic effectiveness of the different types of measures

In the Brussels Region about 10 typical site configurations have been defined, characterized by the number of tracks and the elevation of the tracks with respect to their surroundings. These are summarized below.

Number of tracks	Elevation of track
2 or 4	Below ground level: −6 m, −3 m At ground level: 0 m Above ground level: +3 m, +6 m

For each typical situation the effect of a number of noise reduction measures were examined at a distance of 25 and 50 m from the nearest rail and at heights of 2 and 4 m above ground level. The following measures have been examined:

- Sound screens which were 1, 2 and 4 m high.
- Sound walls (earth bank) which were 2 and 4 m high.
- Low track barriers (results from literature study only).

The report describes in detail the effects of these measures for the different typical site configurations. In addition, the effect of a number of parameters on the basis of results from the literature (shape, absorption coefficient, and distance between the screen and the railway) were studied [1–5]. The main conclusions are:

- When the railway is below ground level, the noise propagation into the environment is considerably lower than when the railway is at or above ground level. At short distances, the difference is not large, but at greater distances (+100 m) the difference can amount to 10 dB or more.
- An earth bank is less effective than a screen of the same height. This partly results from the rounded shape of the top of the bank and partly from the larger distance between the top of the bank and the rail track. The foot of the bank is assumed to be at the same distance from the track as the screen.
- In general, the noise reduction is lower at a reception height of 4 m than at 2 m. If the railway is below ground level, however, the reduction is sometimes larger at a reception height of 4 m.
- The effectiveness of the measures examined is highest when the railway is above ground level. Even with a screen of 1 m high a reduction of more than 10 dB(A) at a reception height of 2 m is obtained. At a reception height of 4 m, a reduction of at least 8 dB(A) was calculated.

- A barrier is considerably more effective when absorbent material is fitted on the inner face. The effect of the absorbent material is largest for the nearest track. For more distant tracks the effect is smaller, but still significant.
- Effective noise reduction can be achieved with a straight and fully absorbent screen. No other shape yields significantly better results, except a sigma-shaped screen with an absorbent top, which gives an additional 1 to 3 dB reduction. For a high speed train (HST) a screen which is inclined towards the track was observed to be the most effective. However, it should be noted that in case of a HST, in contrast to conventional trains, there are also more elevated noise sources. Whether screens inclined towards the railway will also improve performance in the case of conventional trains is not known.
- If the screen cannot be fitted with absorbent material, then it is recommended to incline the screen away from the rail.
- A change in the distance between the screen and the rail tracks has the greatest effect on the track that is closest to the screen. A screen 5 m from the nearest track will be at least 3 dB less effective than a screen at a distance of 2 m. For tracks further away from the screen, the effects of moving the screen are less.
- With absorbent low track barriers noise reductions of on average 4 dB average can be obtained.

3.2.2. Integration of the different types of sound barriers

Possible 'green' variants of sound screens have been considered. For earth walls the study was limited to the proposal of a number of variants for 'green retaining walls'. Table 3 gives a brief description of possible 'green' screens.

3.3. Assessment of noise barriers

Different solutions for noise-reducing measures (both 'green' and 'non-green') were compared using the criteria defined in Step 1. An overview of the assessment results is given in Table 4 [6–9].

Table 3
Description of 'green noise barriers

Measure	Description
A-model screen with vegetation	Two corrugated cortensteel or plastic sheets shaped like the letter A against which trees or shrubs are planted.
Post model screen with vegetation	Cortensteel or plastic sheet against which trees or shrubs are planted on both sides.
Cage construction	Vertical, frame-like posts, connected by steel mesh. Between both meshes a soil mixture is deposited, suitable for a variety of plants.
Stacked construction in concrete	Stacked construction consisting of concrete sleepers and/or boxes. The open spaces in the construction are filled with a soil mixture in which several types of plants can be grown.
Stack construction in wood	Wooden planks are constructed into a parallel double wall. The space between the walls is filled with coarse-grained material, such as rubble or concrete granulate. On a number of places, sacks for plants are inserted.
'Green' wooden screen	Wooden screen against which plants are grown.
'Green' concrete screen	Concrete screen against which plants are grown.

Table 4
Evaluation of sound barriers that can be integrated in the landscape to reduce the propagation of railway noise-summary table

Criterion	Unit	Scale	Green noise barriers								Transparent screen	Screen wood	Screen concrete	Mini-screen
			Growth screen A-model	Growth screen Posts model	Cage construction	Stacked construction wood	Stacked construction concrete	'Green' screen wood	'Green' screen concrete	Earthen wall				
Space required		−− large space requirement, ++ small space requirement	+	++	++	0/+	+	++	++	−−	++	++	++	++
Maximum construction height	m	The higher, the better	>4	>4	6	>7	7.5	5	?	>5	5	5	?	?
Distance to nearest rail track	m	<3 m is bad, 3 m is good	3	3	3	3	3	3	3	3	3	3	3	<3
Accessibility to rail		−− is very bad, ++ is very good	+	+	+	+	+	++	++	+	++	++	++	−−
Acoustic performances														
Insulation-R	dB(A)	The higher the better	>30	>25	>30	>25	>25	>25	>25	>30	>25	>25	>25	
Absorption		Reflective (Ref) Absorbent (Abs)	Abs	Ref	Abs	Abs (layer)Ref	Abs	Abs Ref	Abs Ref	Abs	Ref	Abs Ref	Abs Ref	Abs
Landscape value (visual-spatial)		−− is very bad ++ is very good	++	++	++	++	+	+(+)	+	++	0	0/+	−−	0
Ecological value		−− is very bad, ++ is very good	++	++	++	++ sleeper, + boxes and mixed	0/+	0/+	0/+	+	−−	−−	−−	0
Graffiti-proof		No: not good Yes: good	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes
Necessity of water supply			Sometimes	Sometimes	Yes	Yes	Sometimes	No	No	No	No	No	No	No
Life span of fixed construction	Number of years	The higher the number, the better the score	Corten: 10–15, Plastic: >25	Corten: 10–15, Plastic: >25	>25	>30	>50	15–25	>25–30	Unlimited	Acrylate: 20-25, Glass: >25	15–25	>25–30	
Cost	Euro/m^2	The lower the number, the better the score	220	160	290	200	175	Ref: 165 Abs: 210	350–500	100–400	250–300	Ref: 165 Abs: 210	350–500	

4. Decision support system

As a follow-up of the present study, the development of a decision support system (DSS) is planned. This project has not yet been undertaken yet, and only a brief outline of the possible structure of such a DSS will be given here.

A DSS is a computer-based tool that can be used to assist in a decision-making process. Combining a structural analysis of policy and management issues and the application of information technology, a software tool is designed to help with processing, analysis and

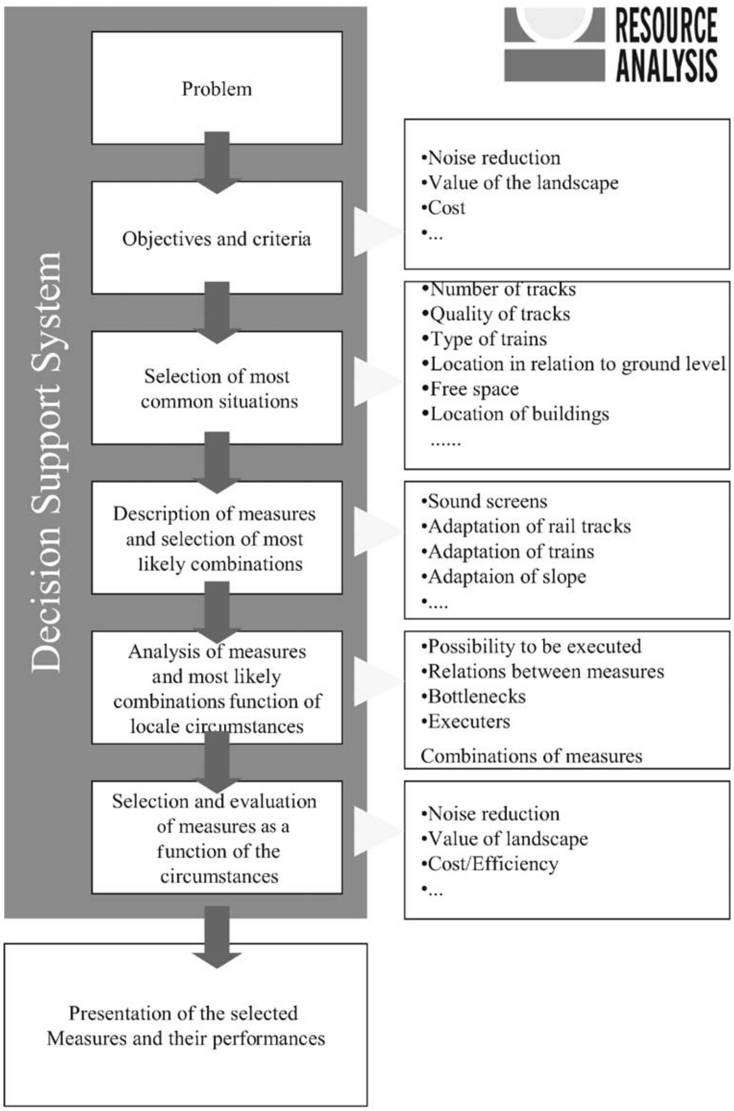

Fig. 2. Schematic overview of the structure of a possible DSS.

communication of information, thereby enhancing the value and effectiveness of the information. In essence, a DSS helps users to acknowledge which information is relevant and at which time.

In the context of the 'Environmental integration of measures to reduce railway noise in the Brussels Capital Region' study, a DSS provides added value in the choice between different solutions for reducing railway noise.

The DSS will allow a selection to be made between alternative measures (directed at both the source and the propagation path) that are being considered to reduce the noise nuisance in a certain location.

By means of a number of multiple choice questions, the user is asked to supply data concerning local conditions (location of the railway, number of tracks, quality of the tracks, type of trains, environmental characteristics, required noise reduction, available space, etc.). Using this information, an expert system selects, from the available measures, the most appropriate measure that will achieve the noise reduction objective, in a way that pays maximum attention to its integration into the landscape. Fig. 2 shows a schematic overview of the structure of a possible DSS.

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