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The STAIRRS project, work package 1: a cost-effectiveness analysis of railway noise reduction on a European scale

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Abstract

Noise control is a major economic factor for the railways as national and European Union environmental legislation is being enacted. In an effort to determine optimal strategies on a European level, the EU fifth framework programme has co-financed the Strategies and Tools to Assess and Implement noise Reducing measures for Railway Systems (STAIRRS) project. Work package 1 developed the necessary software to undertake large-scale cost-effectiveness analyses. The acoustically relevant geographic, traffic and track data were collected for 11 000 km of lines in seven European countries. Standard cost–benefit methodologies were adapted to fit the requirements of the project. An extrapolation mechanism allowed studies on Europe as a whole and, in an approximate manner, also on individual countries. Major conclusions are that the highest cost-effectiveness can be achieved by combining measures; freight rolling stock has a high cost-effectiveness on its own as well as in combination with other measures, especially when combined with track measures; noise barriers, in particular high ones, have a low cost-effectiveness. The conclusions for Europe as a whole are also true for individual countries. The STAIRRS project co-ordinator is the European Rail Research Institute, the work package leader is the Swiss Federal Railways with the participation of AEAT Technology (NL), German Railways, French Railways, PSI-Akustik (A), the Swiss Federal Institute of Technology and the Free University of Brussels.

1. Introduction

Noise control is a major economic factor for the railways as national and European Union environmental legislation is being enacted. It is therefore important for the railways to determine an optimal noise control strategy, allowing for maximum benefits in terms of noise reduction per lineside inhabitant for given cost levels.

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Studies in Switzerland and on two major European freight freeways show significant cost savings if cost–benefit criteria are included in planning. Swiss studies demonstrated that an optimal cost distribution consists of spending 65% of the available finances on rolling stock improvement, 30% on noise control barriers and 5% on insulated windows. This mix protects 70% of the lineside population for 30% of the cost necessary to attain threshold levels for all inhabitants [1,2]. A similar study financed by the International Union of Railways (UIC) on the lines from Rotterdam to Milano and from Bettembourg to Lyon tested different combinations of measures. This study found that optimal solutions include rolling stock improvement, that maximum benefits are achieved at about Euro 60 000/km/year, and that above this value there is no additional benefit in scenarios with higher costs [3]. Studies in The Netherlands showed that a large number of noise barriers will be unnecessary when source measures are applied [4,5]. The total saving for these unnecessary barriers is much higher than the cost for source reducing measures.

2. The STAIRRS project

The Strategies and Tools to Assess and Implement noise Reducing measures for Railway Systems (STAIRRS) consists of three work packages:

- WP1: Railway noise strategy support system.
- WP2: Characterization and classification methodologies.
- WP3: Consensus building workshops.

This paper considers only the first WP (WP1), the objective of which is to provide a European-wide software tool to determine the large-scale environmental impact of railway noise.

3. Computer software: Eurano 2001

Based on the Dutch Gerano program and the UIC-financed upgrade Eurano 1999, a software system has been developed that allows rapid data entry and calculation of costs and benefits by simply changing parameters such as noise creation per train type or costs per unit.

4. Database

Acoustic data were collected for a total length of 10 974 km, representing about 10% of the total line length in the seven countries considered (Table 1).

For the chosen lines the following data were collected and entered into Eurano:

- *Geographic data*: Geographic data consist of the extent of urban areas and individual houses adjacent to the lines. This was determined based on maps to the scale of 1:25 000. Exceptions are Belgium where maps of 1:50 000 and Italy where maps of 1:200 000 were used. In Italy, however, a quality control with maps 1:50 000 was undertaken, where such maps were

Table 1
Line length studied in each country

Railway, country	Length to be studied (km)	Total network length (km)
DB, Germany	4121	38 450
FS, Italy	1557	16 031
NS, The Netherlands	600	3000
OeBB, Austria	480	5627
SBB CFF FFS, Switzerland	576	2939
SNCB, Belgium	330	3422
SNCF, France	3310	31 821
Total	10 974	101 290

available. In France the extent of the urban areas was purchased digitally from a separate organization so that entry was not necessary.

- *Traffic data*: Traffic data consist of the number and composition of trains based on predicted values for the year 2005. If these data are not available current values were used.
- *Track data*: Acoustically relevant elements of the track include type of sleeper (e.g., concrete versus wood), track condition (e.g., welded versus non-welded track) and noisy bridges.

5. Extrapolation procedure

An extrapolation methodology was developed to determine optimal noise control strategies for any geographic area of interest, be it Europe as a whole, the EU or an individual country. Within the choice of lines, the 11 000 km of line length for which detailed acoustical data are available, acoustical line segments were defined. In addition, rough acoustical data were collected throughout Europe to determine the ratio of such segments in the geographic area of interest. Knowledge of this ratio subsequently allows an appropriate database to be chosen in the selection of lines representing the geographic area of interest. Eurano 2001 includes an automatic generator of acoustical line segments.

6. Cost-effectiveness analyses

To determine costs and effectiveness two approaches were used simultaneously:

- *Short-term approach*: Different noise control strategies (for example, consisting of varying combinations of noise control measures) are compared based on investment costs. These control measures have a benefit only during their lifetime. This approach implies that technological advances will progress during the lifetime of the products, thus requiring an analysis and a new decision at the end of their lifetimes. This approach therefore does not include costs to replace control measures.
- *Long-term approach*: This approach assumes that noise target values must be attained over long periods of time. This requires replacement of noise measures at the end of their lifetime so that

these costs are included. The costs and benefits are assessed for long-duration noise abatement. This approach uses the econometric formula for calculating long-term annual payments.

Both approaches compare costs using net present values. However, the benefits are defined in physical terms (i.e., noise reduction per lineside inhabitant) and are called 'effectiveness'. The study is therefore a cost-effectiveness approach. The ratio between the physical benefit function and the cost function is called 'efficiency'.

7. Optimization algorithms

In addition to calculating different control measure combinations on large data sets (representative databases; see above), a methodology was developed to allow the determination of optimal strategies for a specific line under given decision policies.

8. Control measure combinations tested

Table 2 describes the combinations of measures tested.

9. Results

The main results are illustrated in Fig. 1.
The conclusions can be summarized as follows:

- *Noise control is very expensive*: For the 21 countries studied, the total extrapolated present costs range from € 3.5 billion (*k*-blocks on freight wagons) to € 76 billion (allowing a maximum of

Table 2
Combinations of measures chosen

	Freight rolling stock			Track		Noise barriers	
	Freight –10 dB(A)	Composite brake blocks	Optimized wheels	Acoustic grinding	Tuned abs.	2 m	Max. 4 m
0							
1	XXXXX						
2		XXXXX					
3				XXXXX			
4					XXXXX		
5						XXXXX	
6							XXXXX
7		XXXXX	XXXXX		XXXXX		
8		XXXXX			XXXXX		
9		XXXXX				XXXXX	
10				XXXXX		XXXXX	
11		XXXXX	XXXXX	XXXXX	XXXXX	XXXXX	

Windows in all cases, in which thresholds are not attained.
The "0" option indicates the current situation without measures. The numbers in the left-hand column refer to the control combinations illustrated in Fig. 1.

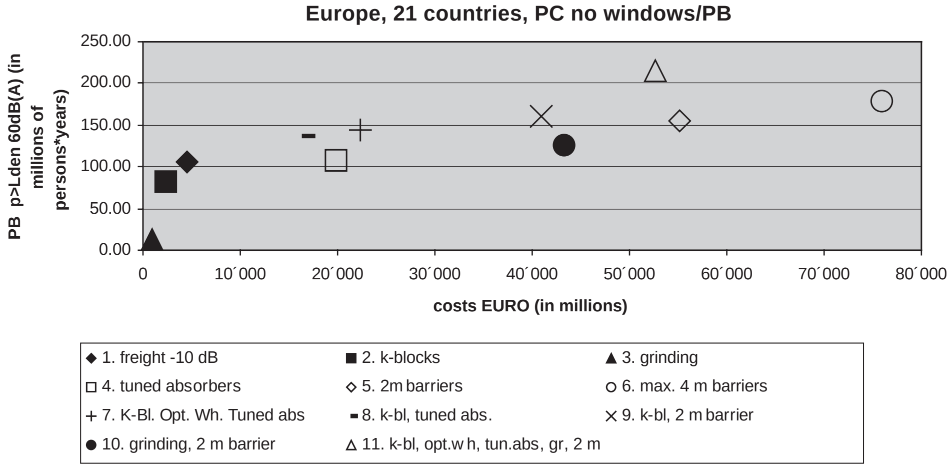

Fig. 1. Short-term cost-effectiveness of programmes not including windows. Number of wagons from UIC action programme noise reduction freight traffic. PC: present costs, PB: present benefits or effectiveness. PB L_{den} $p > 60$ dB(A): effectiveness as reduction of number of persons above L_{den} of 60 dB(A); k-Bl: composite brake blocks, Opt. Wh.: optimized wheels; tun. abs.: tuned rail absorbers, gr: grinding, 2 m: 2 m noise barriers.

4 m barriers). These prices increase if, in the long term, the current costs are taken into account (including price of removal after the end of the lifetime and the replacement of the control measure). Then, the maximal costs are € 109 billion.

- *The benefits of the measures vary*: The best effectiveness can be achieved with a solution combining *k*-blocks (composite brake blocks), optimized wheels, tuned rail absorbers, grinding and noise barriers not higher than 2 m. This solution protects almost 95% of the population (i.e., only 5% of the lineside population have remaining noise above an L_{den} of 60 dB(A)).
- *Freight rolling stock improvement is the most cost-effective*: With composite brake blocks, 38% of the effectiveness can be achieved for about 5% of the cost of the option with the greatest effectiveness.
- *Noise barriers have poor efficiency*: Noise barriers, especially if barriers up to 4 m height are allowed, have poor efficiency. Their effectiveness and efficiency, however, can be improved if *k*-blocks are added, because the total length of noise barriers can be reduced. A similar increase can be expected if tuned rail absorbers are added. However this combination was not tested.
- *Acoustic grinding requires smooth wheels*: The cost of acoustic grinding is very low (present costs of € 1.3 billion). With rough wheels, the effectiveness is poor. It can be increased, however, with measures that provide smooth wheels. This general conclusion is based on TWINS calculations using average roughness data from the literature for cast-iron tread-braked wheels, disc-braked wheels, with normal and smooth rails. A calculation procedure was the only one that could predict the noise effects for different roughness wavelength spectra taking account of a variety of designs and operating conditions. In absence of other data, Austrian data were used to derive roughness spectra for 'longitudinally ground rails'. The benefit is predicted to be low

because from the data available, even for disc-braked wheels, wheel roughness still dominates rail roughness. In specific cases, for example in Germany, measurements indicate a much higher noise reduction from 'acoustically ground rails' where, on average, a 3 dB(A) benefit is achieved for all types of trains irrespective of braking.

- *Track measures in combination with rolling stock measures are highly efficient*: Combining rolling stock improvement with track measures decreases costs while retaining the same effectiveness. Similarly, the effectiveness can be increased and the costs decreased if *k*-blocks are added to a scenario consisting of only tuned rail absorbers.
- *The costs for insulated windows are high with poor effectiveness*: Freight rolling stock solutions may be highly efficient, but they are only about one-third as effective as the maximum solution. Therefore, if all remaining persons exposed to noise reception values above an L_{den} 60 dB(A) receive insulated windows, considerable costs must be expected. These are 4–5 times higher than the costs for the freight rolling stock improvement alone.
- *The above conclusions hold in almost all countries*: Exceptions only occur in those countries that have an exceptionally high number of freight wagons (e.g., France), or an exceptionally low number of freight wagons (e.g., Norway). In these cases only the combination of *k*-blocks with optimized wheels is different, because here the number of freight wagons determines total costs for both elements.
- *Optimization tool tested*: The optimization tool could work in many instances. For those decision policies, the optimization process favours rolling stock solutions, thus supporting the conclusions obtained through the comparison of noise control programmes. Further work on input data configuration is needed to allow wide-scale implementation.

Suggestions for further study include improving the database, especially in terms of urban population densities, and calculating the effects of different thresholds and additional promising combinations of measures such as composite brake blocks (*k*-blocks) combined with tuned rail absorbers and noise barriers.

10. Work partners

The STAIRRS project co-ordinator is the European Rail Research Institute, the work package leader is the Swiss Federal Railways with the participation of AEAT Technology (NL), German Railways, French Railways, PSI-Akustik (A), the Swiss Federal Institute of Technology and the Free University of Brussels.

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