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Railway noise abatement in Switzerland: a progress report

Jakob Oertli
Swiss Federal Railways, Mittelstrasse 43, 3000 Bern, Switzerland

ABSTRACT

Detailed cost-effectiveness analyses based on extensive mapping led to an ambitious railway noise abatement programme in Switzerland. This programme includes 1) rolling stock improvement by retrofitting all Swiss rolling stock with composite brake blocks 2) noise barriers with a cost-benefit constraint, and 3) installing insulated windows where legislated thresholds cannot be achieved with the first two measures. Additional incentives are differential track access charges. The noise abatement programme is part of a package to promote public transportation which is largely financed through taxes on road freight transportation, on gasoline and with the value added tax. This package was accepted by public vote in 1998. The 15 year implementation programme started in 2000 is now in its 9th year: During this time more than 4500 freight wagons (out of a total of 7000) have been retrofitted and about 100 km of noise barriers (out of a total of 300 km necessary) have been constructed. The noise barriers built and the wagons retrofitted to date have made it possible to attain legal thresholds for some 63'000 people out of the total of 250'000 persons with noise levels exceeding thresholds. Once the project is complete, 170'000 people will attain thresholds levels while the rest will receive noise insulated windows. This combination of measures costs only 30 % of scenarios where all persons are brought under legal thresholds.

1. INTRODUCTION

Railway noise is an ever increasing problem. In order to maintain a sustainable transport system, the railways must reduce noise as their main environmental problem. Otherwise political and public support of the railways may decline. In addition noise issues may prevent a traffic increase and therefore hinder the implementation of the European transport policy and its focus on increasing the railway's traffic share.

Railway noise control is also on the European Union's agenda. The Environmental Noise Directive (END) requires noise maps and action plans and the Technical Specifications for Interoperability (TSI) define noise creation limits for new vehicles. The European Union is also planning to introduce differential track access charges and emission ceilings to promote silent freight vehicles.

In Switzerland noise has been an issue for several decades leading to the introduction of noise legislation in the relatively early year of 1987.

2. RAILWAY NOISE TECHNOLOGY

Traffic noise, including railway noise, can be controlled at several different locations:

- **At the source:** Rolling noise is caused by small irregularities on both the wheel and the track in the contact area between the two. Noise reduction at the source can be achieved by either reducing this roughness or by preventing its growth. This is usually attained by either improving the running gear of the rolling stock and/or the track. Lower speeds also reduce noise at the source, but large changes in train speed are required to give noticeable changes in noise and are therefore contrary to efforts to attain a modal shift.

- **Between source and inhabitant:** A further possibility to reduce the impact of noise is by preventing its propagation. Noise barriers (walls, berms, in extreme cases tunnels) are the most common method of noise abatement between the railway lines and inhabitants.
- **Near the inhabitant:** Finally, noise can be reduced in the immediate vicinity of the inhabitant, i.e. on the building itself. This is usually done with insulated windows or facade insulation.

For existing freight vehicles – the main source of noise – retrofitting cast iron brake blocks with composite brake blocks is perhaps the most efficient noise control possibility. This retrofitting usually has an effect of 8 – 10 dB(A). Currently two types of composite brake blocks are being developed and implemented: The K- and the LL-blocks. K-blocks have a higher coefficient of friction than cast iron brake blocks and because of this they require an adaptation of the braking system. LL-blocks simulate the braking performance of cast-iron brake blocks and therefore only minor adaptation of the braking system is necessary. K-blocks have been definitively homologated, while LL-blocks have received provisional homologation.

3. RAIL NOISE CONTROL IN SWITZERLAND

A. Noise legislation

Noise legislation was enacted in Switzerland in 1987 [1]. Additional legislation specifically for railways was enacted in 2000 and 2001. The general noise legislation divides all built over areas into four different sensitivity zones. For each zone noise limits are defined for day and night. Additionally, within each zone, three types of limits are defined, i.e. for new structures or infrastructure, for existing areas and a so called alarm value which helps set priorities. The noise limits are the same for all modes of transportation, however the calculation algorithm varies from mode to mode. The railways receive a noise bonus between 5 and 15 dBA, depending on the traffic levels while road traffic received a bonus of 0 – 5 dBA. The limit values are given in Table 1.

Sensitivity Level	Planning values		Regular values		Alarm values	
	day (dBA)	night (dBA)	day (dBA)	night (dBA)	day (dBA)	night (dBA)
I (special areas e.g-hospitals)	50	40	55	45	65	60
II (residential zones)	55	45	60	50	70	65
III (mixed zones)	60	50	65	55	70	65
IV (Industrial areas)	65	55	70	60	75	70

Table 1: Limit values for existing railways in Switzerland. Note that calculation algorithms vary from country to country so that the values cannot be compared directly with those from other countries.

B. Measure combination as a result of optimization

In order to obtain optimal noise control, costs and benefits of different measures and combinations of measures were calculated based on extensive noise mapping. The results are shown in Figure 1.

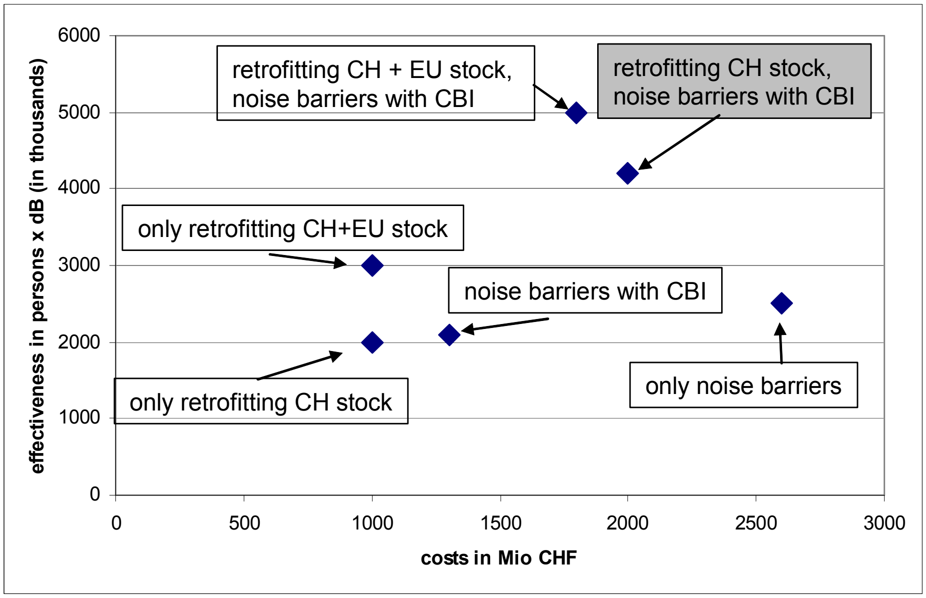

Figure 1: Costs and effectiveness of different rail noise mitigation possibilities in Switzerland. The chosen solution is highlighted. CBI: cost benefit index, CH: Switzerland, EU: European Union.

The optimisation led to the following conclusions:

- Retrofitting the rolling stock has the best cost effectiveness.
- Noise barriers have a very poor cost-effectiveness, unless they have a cost-benefit constraint, i.e. they are only built in areas where they are effective.
- The best solutions are, if retrofitting is combined with noise barriers (with a CBI constraint).
- The cost-effectiveness is even increased dramatically, if the rest of Europe retrofits their rolling stock as well.

D. Overall elements of the project

The above optimisation calculations led to the choice of the following project elements:

- Noise barriers with a cost-benefit constraint.
- Retrofitting all Swiss rolling stock with K-blocks.
- Installing insulated windows in all cases, where threshold cannot be achieved with noise barriers or retrofitting.

In recent years additional measures have been added to the programme: E.g. rail lubrication may be used against curve squeal in certain cases or the noise of steel bridges is reduced with elastic elements.

This combination of measures is designed in such a way, that noise barriers and retrofitting allow two thirds of the affected population to be under legal thresholds, while the remaining third received insulated windows. This optimisation costs only 30 % of the amount necessary to protect most people with noise barriers.

Additional elements of the programme are noise creation ceilings. Anticipated traffic for the year 2015 led to the calculation of noise creation ceilings. After that year, the Swiss Federal Railways are responsible to attain all threshold based on traffic changes. Until that time, noise mitigation is paid for by the government (see below).

Finally, as an incentive for railways not based in Switzerland, noise differential track access charges give a financial benefit to those operators using silent wagons.

The individual elements are discussed in greater detail below:

E. Specifics for noise barriers

The main element for determining the location of noise barriers is the cost-benefit index (CBI). This index facilitates the assessment of the economic viability of structural measures along the emission path.

For CBI calculation the area around an existing track section is divided into sub-areas according to the following principles: The tracks always form the border of a sub-area and the area that is subject to a high level of noise is normally divided perpendicular to the tracks so that the sub-areas that are created are as uniform as possible with regard to topography, settlement structure, building density, allocation of levels of noise sensitivity and land use planning and that have as little influence as possible over each other in acoustic terms.

The CBI is calculated using the following formula:

$$\frac{\text{Cost}}{\text{Benefit}} = \frac{\Sigma\,(\text{cost rate x section length of the measure})}{\Sigma\,(\Delta\text{dB(A) weighted x number of persons})} \qquad [\text{CHF/dB*Persons}] \quad (1)$$

A predefined cost per running meter is determined by the legislation depending on the height of the barrier. This insures equal treatment throughout the network. The calculation of the benefits is weighted, so that noise reductions at higher noise values count more than at lower values.

The consequence of the CBI is that noise barriers are only built in areas, where a good cost-effectiveness can be achieved (compare Figure 2)

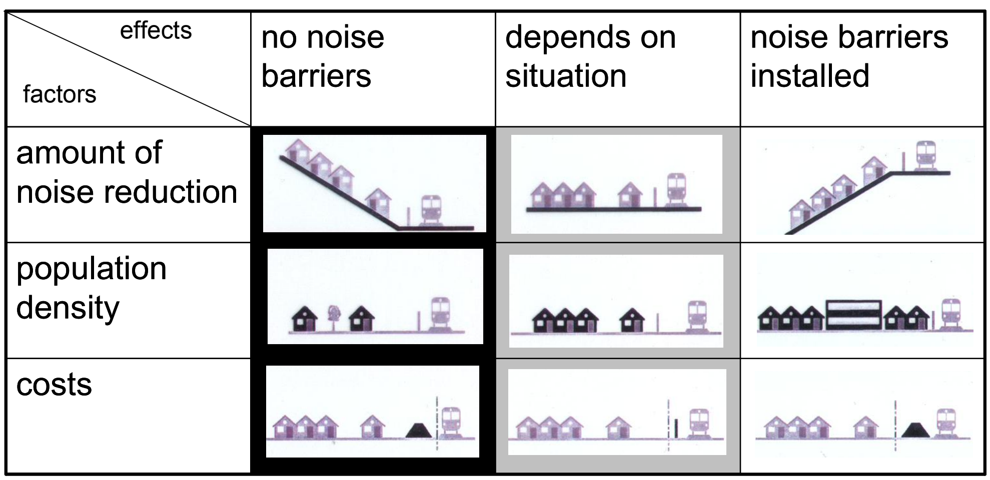

Figure 2: Influence of cost-benefit index on noise barriers

In an effort to create a similar architectural picture throughout the network, two main designs were chosen: A concrete barrier in anthracite and a wooden barrier. On bridges aluminium is usually used, in exceptional cases such as railway stations glass or gabions are used to support nature or landscape protection.

F. Specifics for retrofitting

One of the main difficulties in retrofitting is the engineering. Since retrofitting with K-blocks requires an adaptation of the breaking system each wagon type must undergo separate engineering and testing of the braking performance. In addition to retrofitting with K-blocks, the Swiss Federal Railways are involved in operational testing of LL-brake blocks.

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G. Specifics for noise insulated windows

In contrast to noise barriers and retrofitting, the planning and instalment of noise insulated windows is not the responsibility of the railways but rather of the cantons. Above the alarm values (compare 3.1) the windows are paid for completely by the government, between the noise reception threshold and the alarm value, government financing provides for a 50 % of the costs.

H. Specifics for noise emission ceilings

For each line section, the government in cooperation with the Swiss Federal Railways, defined emission ceilings based on a traffic prognosis for the year 2015. This prognosis includes the retrofitting of Swiss rolling stock. Government financed noise barriers are constructed based on these ceilings.

After the year 2015 it is the sole responsibility of SBB to maintain noise levels. Therefore, if additional traffic is planned on a given line or if the speed is increased, SBB must simultaneously implement noise reducing measures, if this results in noise levels above the predefined ceilings.

The noise ceilings are very precise and continuously change along the line depending on factors such as speed, type of track or rolling stock composition.

I. Specifics concerning differential track access charges

In order to motivate foreign operators to retrofit their freight fleet, a noise differential track access charge was introduced. Currently operators with silent wagons receive 0.5 Swiss cents per axle and kilometre. This amounts to about 6 – 8 % of the total track access charge. An effect on foreign operators has not been observed to date. However if neighbouring countries adopted a similar policy, this might prove to be an important incentive.

The system works with self-declaration, i.e. each operator fills out forms with the amount of km and axles driven and gets the bonus reimbursed at the end of the ear by the infrastructure operator, who in turn is compensated by the government. This low tech solution is pragmatic, could be introduced quickly and there are only little costs for distinguishing loud from silent wagons.

J. Time schedule

Rail noise abatement was defined as a project to last from 2000 to 2015. The retrofitting of all passenger vehicles was completed in 2005 and freight wagons are about halfway through and should be complete by 2010. All noise barriers should be built and all windows should be installed by 2015.

K. Financing

In 1998 the Swiss public voted on a public transportation financing bill including noise control. This package is alimented by taxes on trucks and gasoline as well as the value added tax. This results in road traffic paying for a large part of railway noise abatement.

L. Monitoring of noise creation by the government

The maximum noise creation level for 2015 was defined for each line (noise ceilings). The progress towards achieving these goals is continuously monitored by the government in five locations.

4. CURRENT PROJECT STATUS

As of mid 2009

- 110 km of noise barriers were built (out of about 300 km necessary)
- 4700 freight wagons were retrofitted (out of 7000 necessary)

- 1000 Passenger wagons retrofitted (the entire fleet of passenger wagons is now silent)

As a result there are now 63’000 (out of 250’000) persons newly under the legislated thresholds. The increase in the number of persons under the threshold is not linear because just a few loud freight wagons in a train can cause a large noise nuisance. The additional number of inhabitants under thresholds will therefore increase rapidly in later stages of the project.

5. SPECIAL PROBLEMS

The project is now more than halfway complete and during this time several special problems were noticed:

Nature protection: Because the railway embankments are often valuable biotopes, special care must be taken that the living spaces of animals and plants are not destroyed. For this reason, special constructions are chosen that permit small reptiles to crawl through the barriers. Additionally in the planning process an environmental impact assessment is made of each barrier.

Figure 3: Living space and possibilities to cross noise barriers for small animals

Landscape protection: In many places the tracks run through areas of outstanding scenic beauty or through historical towns. In these cases special care is taken, that the barriers are not disturbing, so that other designs are used (i.e. construction out of wood or with gabion baskets).

Figure 4: Scenic lakeside requiring a special solution

6. LESSONS LEARNED

Specific railway situation important for noise abatement
The particular circumstances in which railways operate must be taken into account when considering solutions for railway noise: Railways operate in a very tight competitive market. Each investment influences competitiveness and must be considered very carefully. Therefore outside financial support is necessary.
Normally freight wagons are only replaced after a very long life span. A satisfactory noise reduction cannot be achieved merely through the normal replacement of existing wagons. A retrofitting of existing wagons is therefore necessary.
Many stakeholders with different agendas are involved. These include operators, infrastructure owners, governments and lineside inhabitants. All of these must be involved if a satisfactory solution is to be found.

Optimization studies save money
In Switzerland scenario and optimization studies led to considerable savings. The chosen combination of rolling stock improvement, noise barriers and insulated windows costs only 30 % of solutions consisting of only noise barriers.

Government support necessary
Due to the tight competitive environment and the complex organisational environment in which railways operate, government support proved necessary. Swiss policy promotes railways as a sustainable means of transportation and therefore it became possible to finance noise abatement as part of a larger package to support public transportation with taxes on the road sector. This policy was supported by public vote in 1998.
The European Commission has a similar policy. In a White Paper the Commission realises that the railways are the most environmentally friendly means of transportation, both for freight and passenger traffic and proposes to increase the railway's market share. Therefore, arguments for state support can also be made on a European level.

Public reaction
Public reaction to the abatement programme is overwhelmingly positive, even if certain communities do not receive noise barriers due to cost-benefit constraints. Having a clear project and time frame that applied the same standards throughout the country is highly appreciated.

7. CONSEQUENCES FOR EUROPE

These results hold true for Europe as a whole as well. Both the EU and the UIC (International Union of Railways) have undertaken cost-effectiveness analyses. The most comprehensive study was STAIRRS (Strategies and Tool to Assess and Implement noise Reducing measures for Railway Systems) [2,3,4] project, co-financed by the EU fifth framework programme and by the UIC. In this project acoustically relevant geographic, traffic and track data were collected for 11'000 km of lines in seven European countries. Major conclusions were: Good cost-effectiveness can be achieved by combining measures. Freight rolling stock improvement has the highest cost-effectiveness both on its own and in combination with other measures. And noise barriers, especially high ones, have a low cost-effectiveness.

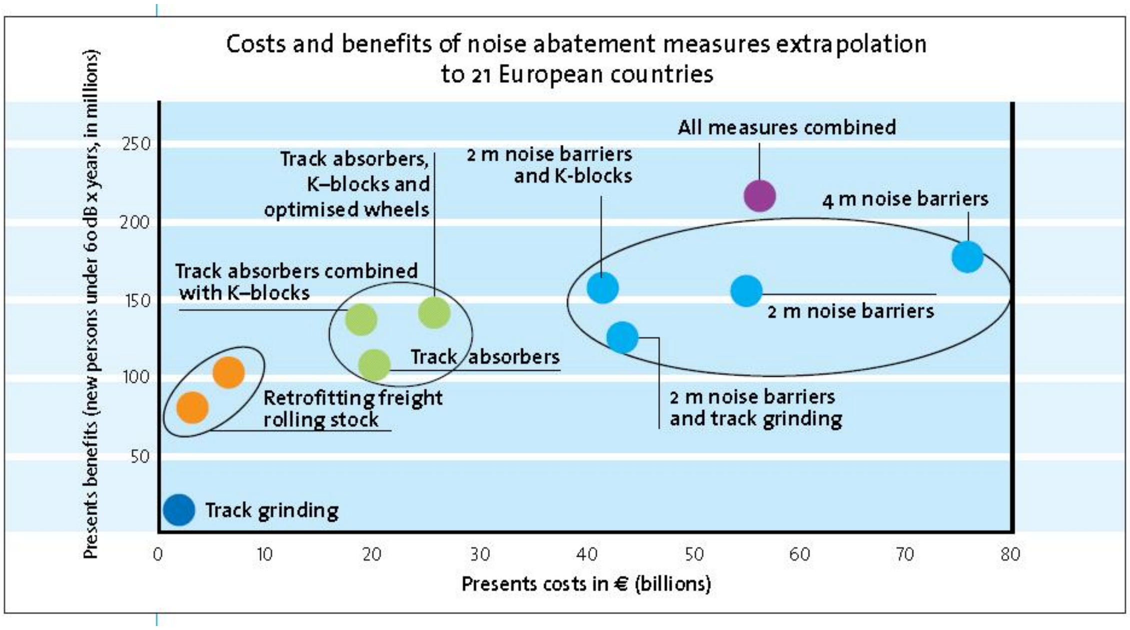

Figure 5: Costs and benefits of different noise control measures in Europe

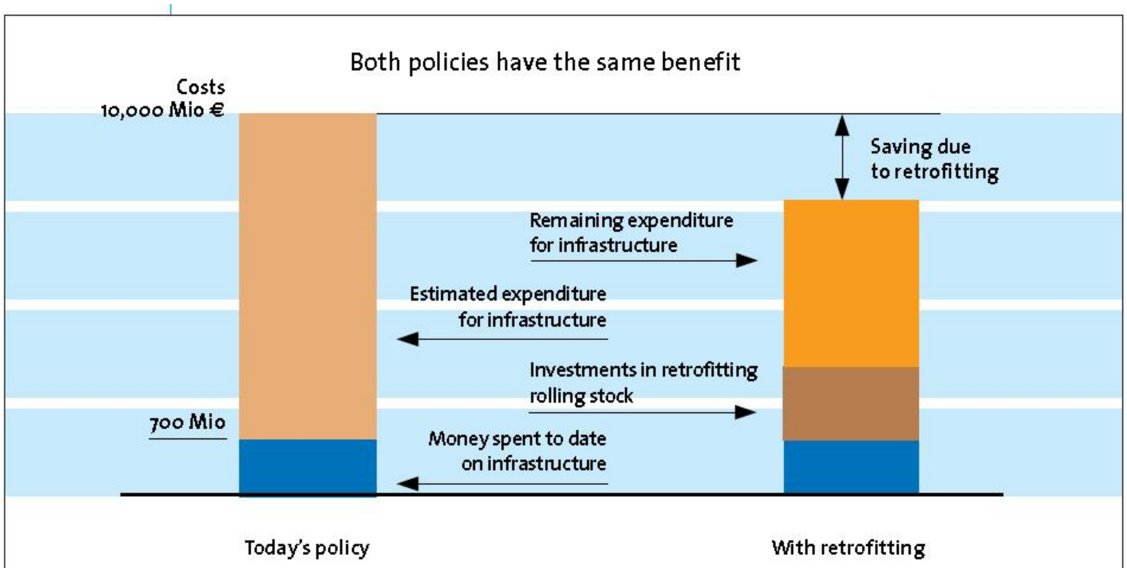

Figure 6: Possible savings in Europe with retrofitting instead of noise barriers. The graph only includes planned noise barriers, which is why the overall noise barrier costs are smaller than in the STAIRRS project (Figure 5).

9. CONCLUSIONS

Overall conclusions are:

Railway Noise Abatement crucial for a sustainable transport system: The railways are a sustainable means of transport; however noise issues must be addressed, if restrictions on rail freight traffic are to be avoided.

Retrofitting saves money: Noise abatement solutions using freight wagons with composite brake blocks are cost-effective and save considerable amounts of money in comparison to solutions including only noise barriers.

Outside financial support necessary for railway operators: Due to the harsh competitive transportation market, the railways are currently not in a position to finance retrofitting.

REFERENCES

[1] J. Oertli, "The STAIRRS project, work package 1: a cost-effectiveness analysis of railway noise reduction on a European scale", *Journal of Sound and Vibration* **267**, 431-437 (2003)

[2] J. Oertli, "Developing noise control strategies for entire railway networks". Journal of Sound and Vibration **293**, 1086 – 1090 (2006)

[3] J. Oertli, P. Hübner "Noise reduction in rail freight, a 2007 report on the state of the art", UIC, 2008

[4] J. Oertli and D. Wassmer, "Rail Noise Control in Switzerland: Legislation, Environment, Politics and Finances", Journal of Sound and Vibration **193**, 403 – 406 (1996)