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NOISE IMPACT SIMULATION OF ROLLING STOCK IMPROVEMENT: SPECIFIC CASE STUDIES IN SWITZERLAND

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Planning cost-effective noise abatement measures can be improved by computer simulation. The method used in Switzerland is illustrated by use of a specific case study in the community of Rheinfelden. Two different interlinked models are used to determine investments and reduction of noise exposure. First, conflict zones are identified in a 2-D model. Then, with detailed information on topography, location and height of buildings, 3-D modelling is used to determine best noise abatement measures in the case study situation. The computer simulation compares different scenarios including improved rolling stock, noise abatement barriers and insulating windows. The results show that improvement of rolling stock reduces the costs for other noise protection measures. However, cost effects of rolling stock improvement in this specific case are much lower than in the average over the entire railway network. This is a typical result for regions with high noise exposure values. It also shows that an optimization of investments in noise abatement measures must take into account at least a representative part of the network, including areas with different noise levels.

1. INTRODUCTION

Swiss legislation enforces public and private companies to invest in noise abatement measures if defined target values for noise exposure are exceeded [1]. Thus, Swiss Federal Railways are obliged to reduce the noise impact on the most frequently used part of its network [2, 3]. The following questions must therefore be addressed:

Where are noise abatement measures necessary?
What do these noise counter-measures cost?
What are the overall costs for noise abatement measures?

A simulation program based on a geographical information system has been developed to solve these problems. In order to illustrate the methodology used, a ase study in the community of Rheinfelden is described. The community of Rheinfelden lies on the transit line Basel-Chiasso, about 20 km from Basel. It has

10 332 inhabitants; about 25% of them are affected by railway noise. Residential and industrial zones are on both sides of the railway track.

The process from the identification of the conflict zones to the definition of the optimal solution for investments in noise abatement measures is described in the case study.

2. ZONES OF CONFLICT

As a first step, the “zones of conflict” have to be identified. These zones are regions where noise values are expected to be above the threshold values. An accurate determination of these zones reduces the costs of data gathering for the detailed noise calculations which follow.

The method of calculation is quite simple. Values of the noise generated (emissions) are assigned to the average geometry of the railway tracks. The noise attenuation is then calculated using a 2-D model taking into account only the distance between noise source and noise receiver point. Two assumptions that are made that there is flat terrain and constant distance between noise source and terrain. The 60 dB (A) contours are determined for these conditions. They represent the boundaries where noise levels higher than target values can be expected. The combination of the population data and the 60 db (A) noise zones gives a first estimate for the zones of conflict.

3. NOISE MAP

Precise information about noise exposure at specific points is provided by the noise map. For this purpose, noise reception points are assigned to the buildings in the defined zones of conflict. The corresponding threshold values depending on the utilization of the zone (industrial, residential, recreational) are assigned to the reception points.

Supplementary information must then be included for the more detailed noise calculation based on a 3-D model. This means that information about the topography of the terrain, the location and the heights of the existing buildings and existing noise abatement barriers have to be introduced into the system. Noise emission values are assigned to each railway track, together with the exact height of the tracks.

Figure 1 shows a small part of the noise map of Rheinfelden. Data boxes which contain the results of the noise calculation are assigned to each defined reception points. In the first column the height of the reception point above ground is indicated. There is approximately one reception point per floor. The second and third columns show the noise reception in dB (A) during day and night time, respectively. When the so-called “emmission threshold values” are exceeded, the relevent blocks of the table are shaded. A dark grey shade means that noise exposure exceeds even the “alarm threshold value”.

Interpolation between calculated values at the reception points could easily lead to erroneous results. The discontinuities in the actual 3-D topography (building

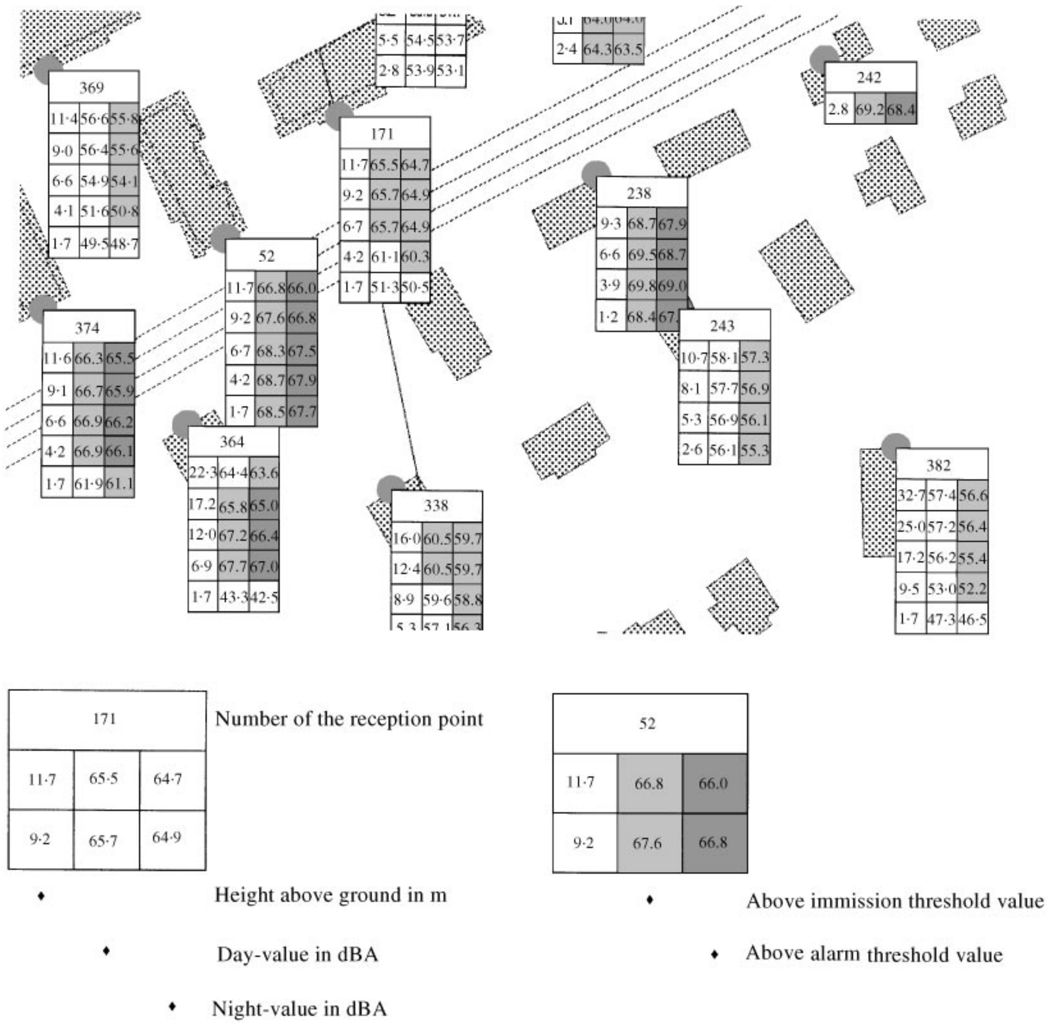

Figure 1. Part of the noise map of Rheinfelden.

walls, terrain changes, etc.) are too significant to ignore and often a meaningful interpolation between the calculated noise values cannot be made. Therefore no contours are drawn.

4. DECISION SUPPORT SYSTEM

4.1. NOISE ABATEMENT MEASURES

The noise map depicts the situation without any noise protection measures. To reduce noise exposure to below the target values, different noise abatement measures can be taken such as by noise reduction at the source point by improving the rolling stock, by protection from noise by constructing noise barriers or by

TABLE 1

Different scenarios of noise abatement measures

Scenario A	8 m noise barriers	Noise barriers up to a maximum height of 8 m. If still excessive noise remains, sound-proof windows are installed
Scenario B	Reduced noise barriers	The maximum height of noise barriers is reduced to 4 m for reasons of landscape protection
Scenario C	Noise barriers with a cost/benefit index < 80	The maximum height of noise barriers is reduced to 2 m. Noise barriers are only considered if the defined cost/benefit index is below 80
Scenario D	Additional improvement of Swiss rolling stock	The Swiss Railways improve their rolling stock. The noise creation is diminished. Where noise reception still exceeds the threshold values, noise abatement measures as in scenario C are taken
Scenario E	Additional improvement of international rolling stock on the network	Further reduction of noise creation is obtained when most of the rolling stock on the network is improved. All other assumptions are the same as in scenario D

installing sound-proof windows. These three measures have different effects either globally or locally. Improved rolling stock reduces noise emission over an entire section of the railway network. Noise barriers have a local effect and sound-proof windows reduce noise exposure at a specific point. As the density of the population varies along a section, a combination of measures leads to the optimal solution with respect to investments and noise reduction.

The decision support system is able to handle the noise effects of the track quality, but noise reduction by reducing the roughness of the track are not considered in the case studies.

4.2. DEFINITION OF SCENARIOS

To compare the results of different noise reduction strategies, five different scenarios are defined for the community of Rheinfelden. They represent the main strategies examined in Switzerland (Table 1).

5. RESULTS

The different scenarios are introduced as input data in the computer simulation program. Corresponding life cycle costs (Table 2) are then calculated automatically according to the following rules. The cost of the noise barriers is determined by the

TABLE 2

Cost comparison of different noise abatement strategies in the case study in Rheinfelden

Scenario	Total length of of noise barriers in m	Cost of noise barriers (1000 CHF)	Cost of insu-lating windows (1000 CHF)	Total cost (1000 CHF)	Cost Differ-ence comp-ared to scenario D (1000 CHF)
A	4535	26958	627	27585	15776
B	4658	19332	1456	20788	8979
C	4503	11708	3753	15461	3652
D	3289	8552	3257	11809	0
E	2623	6818	2383	9202	– 2607

multiplication of the surface area and an average cost per square meter. The costs for insulating windows are estimated by multiplying an average cost factor and the number of citizens to be protected by sound-proof windows.

Scenario D is considered as the base scenario. It is the strategy chosen for noise abatement measures in Switzerland. Comparison of the results of the different scenarios in the case study allows some conclusions to be drawn.

When the maximum height of the noise barriers is reduced, the cost of the barriers is reduced almost in proportion, as the overall length of barriers remains almost constant. It would be more cost effective to invest in sound-proof windows. However, Swiss regulations allow this counter-measure only when noise barriers are in place; otherwise it would lead to excessive cost compared to benefit (Cost Benefit Index (CBI) $>$ 80) [4, 5].

Comparing costs between scenarios C and D indicates the amount of money saved on noise barriers and windows when the Swiss rolling stock is improved. Obviously, an even greater saving is achieved when all wagons circulating on the tracks are improved (scenario D).

The cost reduction due to rolling stock improvement leads to cost reductions of other noise protection measures in Rheinfelden of 3 652 000 CHF. Further improvement of rolling stock could save another 2 607 000 CHF. Compared to the savings achieved over the entire the Swiss Railways network the cost savings in Rheinfelden are not impressive. This is explained by the fact that in Rheinfelden the existing noise exposure values are well above the threshold values, and whilst the improvement of rolling stock reduces noise emissions, the noise exposure remains above the threshold values. This is typical of a situation where existing noise exposure levels values are high and the area near the railway track is densely populated.

The cost savings through improved rolling stock is much higher on sections of the network where other noise protection measures become unnecessary. Thus, optimization of investments in noise protection measures must take into account at least a representative part of the entire network, including both noisy and quiet sections.

6. CONCLUSIONS

Planning cost-effective noise abatement measures needs detailed information on noise sources, topography and the number of citizens to be protected. Combination of all these data leads to a complex planning scenario. To reduce the complexity a three-stage top–down approach can be used.

Before starting detailed noise studies an overview of the situation is made by using a simple 2-D model for noise calculations. The results determine the zones of conflict where noise exposure values are expected to exceed a defined threshold.

More detailed noise calculations then require a 3-D model to take into account topography, buildings and noise attenuation by the buildings and other obstacles. The results are represented by a noise map.

Optimization of investments in noise reduction measures are performed by means of the decision support system, based on the noise map. Simulation studies compare different noise abatement strategies.

The case study in Rheinfelden shows that improvement of rolling stock leads to cost savings. However, these are less significant than expected when compared to the results obtained on the entire network of Swiss Railways. The reason is that Rheinfelden is on the Gotthard line with one of the highest noise emission values and the areas close to both sides of the track are built up. Even with reduced noise emission values, exposure threshold values are exceeded. It must be stressed, however, that despite small cost savings, the inhabitants will still perceive an overall benefit from rolling stock improvement.

In general, cost savings by improved rolling stock are more important on sections of the railway network where noise exposure values are near the threshold values. Therefore, optimization of investments in improvement of rolling stock must consider representative parts of the network.

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