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A MODEL TO OPTIMISE THE DIMENSIONS OF ROADSIDE NOISE BARRIERS

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1. INTRODUCTION

Barriers erected alongside carriageways to screen residential areas from high levels of traffic noise have been employed for a number of years. Barriers in the UK are often simple wooden constructions rarely exceeding 3m in height. In Europe and North America many different types of barrier have been installed using a wide variety of materials, including steel, aluminium, concrete and acrylic sheeting. Some of these have absorptive facings on the traffic side which reduce reflected sound and can, under certain conditions, improve screening. Barriers over 5m in height have been used and imaginative designs have been employed. The acoustic and aesthetic acceptability of these barriers is being assessed and it is clear that unit costs will be significantly higher than for conventional wooden barriers. There is a need for a barrier optimisation program which will achieve the required degree of screening at minimum cost. There may be for example, considerable scope for savings if restrictions on maximum height and shape are relaxed so that solutions are allowed other than simple rectangular (constant height) barriers.

A noise barrier optimisation program is described which enables a shaped barrier to be designed to reduce noise levels at receptor positions to below any reasonable chosen value and at a potentially lower cost than an equivalent rectangular barrier. The program allows for the specification of required (target) noise levels at a number of receptor positions and it is flexible enough to cope with a varying ground profile adjacent to the carriageway. The program was written initially in HP Basic and runs on an HP 9836C microcomputer.

2. PROGRAM DESCRIPTION

2.1 Overview

The program builds the barrier block by block until all the noise levels at the receptor positions are below the target levels. The methods defined in the Calculation of Road Traffic Noise (CRTN) [1] are used in all the computations. The road noise is treated as a simple line source and the barrier is "constructed" parallel with this line at a given distance away. The height profile of the line along which the barrier is built is defined in order to model such features as cuttings and embankments. The barrier block height and length are specified together with the length of road (segment) alongside which the barrier is allowed to be built. This segment is divided into intervals of one block length.

After all the relevant information is entered a subroutine examines each receptor in turn in order to determine at which location the greatest difference occurs between current and target noise levels. Next, a block is placed on the ground profile along the segment at each interval in turn and at each position the drop in intensity is calculated at the chosen receptor position. After each block position is checked the block is placed at the interval which produced the largest drop in intensity. The sound level at each receptor is then recalculated and again a receptor is chosen for which the greatest difference exists between the new current noise levels and target values. A second block is then placed at each interval in turn and on this occasion it will be placed over the first block when this particular interval is examined. After each valid position is checked this second block is placed at the location which results in the greatest drop in intensity at the chosen receptor position. This position could be on top of the first block or directly on the ground profile. The noise levels at all the receptors are recalculated to take account of this second block and again a receptor is chosen where the difference is greatest between the current and target level. The process is repeated with other blocks until the noise levels at all receptors are below their target values. This process is shown on the VDU so that the user can quickly appreciate how the overall shape is determined. It has been found that for a single receptor on a flat ground plane the overall shape is very approximately Gaussian, (see Figure 1). For a multiple receptor problem the individual Gaussian shapes determined for each receptor will tend to merge depending, of course, on the positions of the receptors and their target noise levels (see Figure 2).

2.2 Program structure

The program can be viewed as a series of stages as shown in the flow diagram in Figure 3.

Stages 1 and 2 : The first two stages involve entering the basic data eg the coordinates needed to define the variation of the ground profile along the line of the barrier (ten are required in the current version), the positions of the receptors, and the target noise levels at each receptor. The user has the choice of entering the noise level generated by traffic before corrections are made for distance, screening, angle of view, reflections etc, or the traffic and road data can be entered and the program then completes the necessary calculations. The user also enters the average height of propagation (see ref. [1]) for each of the direct sound rays drawn from the source line adjacent to the ten ground profile coordinates to the receptors (see Figure 4).

Stage 3 : For each of the ten points on the segment a sub routine computes the minimum height of the barrier such that the barrier potential correction just exceeds the correction due to ground absorption. This information is needed by the user in order to define the minimum height of the barrier. If the minimum height is set below these values the program cannot yield an optimum solution because placing such a small block on the ground profile produces no reduction in the noise intensity at the receptors : in this case the potential barrier correction for the block will be less than the ground absorption correction applying before the block was placed. This is consistent with the procedure detailed in the CRTN method [1].

The height of subsequent blocks (ie those that will be placed on top of the blocks of minimum height in contact with the ground profile) is then entered. For realistic solutions it may be prudent to base block dimensions on a knowledge of manufacturers' panel sizes. Experience has shown that often block heights between 0.4 and 1.0m are suitable.

The maximum height of the barrier above the ground is also entered. This might be restricted by aesthetic considerations, for example a barrier over 5m high might be judged visually intrusive by residents. When completing a run it is often clear when a maximum height restriction might not lead to an optimum solution since a plateau-like shape results instead of the more normal shape resembling a Gaussian curve.

The costs of a metre run of barrier 2 and 3m high are also entered so the cost of the completed barrier can be calculated. For this purpose it is assumed that the cost is a linear function of height. If required, it would be possible to modify the program so that a cost versus height function could be entered. The first result produced by running the program is a minimum area solution. This will of course yield a barrier shape of minimum cost if the cost is directly proportional to barrier height.

Stage 4 : Here the initial calculations are made involving the computation of barrier potentials and ground and angle corrections for each possible block position and for each receptor position. These calculated values are held in arrays as intensity levels. A further subroutine calculates the noise levels at the receptors prior to the construction of the barrier. These calculations take account of the ground profile and average heights of propagation, and the assumption is made that outside the defined segment the values of these parameters are identical to those at the extreme ends of the segment. The graphic display is also set. This shows horizontal and vertical distance scales and an outline of the ground profile is drawn along the line of the intended barrier.

Stage 5 : This includes the main routine to calculate the position of the blocks to maximize the noise reduction at the receptors. This is achieved by calculating the change in intensity values at the chosen receptor (ie the receptor where there is the greatest difference between the current noise level and the target level) for each interval in the segment. The computation time is reduced by using stored values of barrier potential and angle corrections calculated in stage 4. To determine the interval where the maximum reduction in intensity is produced when a block is placed, the routine first calculates the difference in intensity at each interval in turn due to the change in barrier potential following the addition of a block, or, if a block has not already been placed the difference between the potential correction for the first block and the ground absorption correction. Secondly, this difference is factored by the adjustment for intensity due to the angle of view correction. The resulting value will be highest where the intensity reduction at the receptor is greatest since all other contributions to intensity are constant across the intervals eg distance correction, and corrections due to traffic and road parameters. Once the interval has been identified a block is placed at this position in the graphic display and the correct adjustments to the running totals of intensities at the receptor positions are made. Barrier building continues until all receptors are below their respective target values. As the calculations proceed, blocks are added to the graphical display of the barrier and the current and target noise values are given for the current chosen receptor.

Stage 6 : Finally, the total area and cost of the barrier is calculated and printed. A routine determines the final heights of the barrier at each interval in turn and the cost is calculated by interpolating or extrapolating from the previously entered cost data. The total area and cost is obtained by summing over all intervals. The length and maximum height of the barrier are also given and the graphical display is dumped to a printer. Using a compiled version of the program a typical run with several receptors takes only a few minutes to complete. Some modest reductions in total area can sometimes be achieved by small adjustments to the minimum height or block dimensions.

Stage 7 : The first solution is one which minimizes area. This does not necessarily minimize total cost if the price per unit length of barrier is not directly proportional to barrier height. One approach that has been successful in reducing costs below that of the minimum area solution uses an iterative technique. Further solutions are obtained by entering a range of cost factors (x) which weight the change in intensity calculated at each interval by c^x where c is the cost of placing a block at a particular height. The program prompts the user to enter the range of cost factors and the required increment and a series of solutions are produced which can be examined to indentify the barrier shape of minimum cost. For example the cost of placing the first block can be relatively expensive because of the fixed costs associated with clearing and levelling the ground. Figure 5 shows the linear cost function for a typical wooden barrier which would be computed by extrapolating from cost information at 2 and 3m. The cost of placing the first block of height 1m is £50 whereas the cost of placing further blocks of similar dimensions above this first one is £30. A negative cost exponent will tend to inhibit the placing of blocks on the ground and will result in a barrier of greater maximum height and smaller overall length and therefore lower cost than a barrier shape resulting from minimising area where a zero cost factor applies. When using cost information from a range of barrier types, savings of up to approximately 10 percent of the total costs of a shaped barrier calculated in stage 6, where no cost weighting is applied, have been found for factors in the range -1 to 0.

3. COMPARISONS WITH RECTANGULAR SOLUTIONS

To test the possible benefits of this program in terms of savings in material where barrier costs were assumed for simplicity to be proportional to total area, several runs were carried out for a single receptor where the reduction in noise level required varied from 3.8 to 10 dB(A). The receptor was positioned 3m above the carriageway and at distances of 30,60 and 100m from the edge. The road surface was level and crossed a flat grassy plane in a straight line. The line of the barrier was 6.5m from the edge of the carriageway. The resulting total area of the barrier was compared with the results obtained from a program which was developed to obtain the best possible solution for a barrier of constant height. As can be seen in Table 1, at all positions and for all noise reductions the shaped barrier solutions resulted in a smaller total area than did the constant height barriers. Figure 6 shows how total area varies with screening requirements for the two barrier types. The indications are that large savings are possible in situations where large noise reductions are required. An examination of the dimensions of the two types of barrier show that the shaped barrier has a slightly higher maximum height and greater overall length than the corresponding rectangular barrier.

4. APPLICATION

In practice the shaped barrier could be produced by stepping the barrier panels as indicated by the graphic display or by using an earth bund in which case a smooth shape could be obtained by joining the mid-points of the upper surface of the top blocks. It would also be possible to produce a practical screen from a combination of earth bund and conventional constant height barrier. For certain situations, especially where a high barrier was needed, the tapered ends of the shaped barrier might prove visually more acceptable than the ends of a rectangular barrier. The program can also be used to specify the optimum length and position of a constant height barrier for a given degree of screening. This can be achieved by setting the minimum height of the barrier to the final height and specifying blocks with a small height dimension. This forces the program to build a barrier with only the minimum height blocks.

5. CONCLUSIONS

A program has been developed which enables a barrier shape to be defined which can provide specified degrees of screening at a number of receptor positions. Comparisons with optimised rectangular solutions indicate the potential for achieving useful savings in terms of barrier materials and costs.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

[1] Department of Transport and Welsh Office. 'Calculation of road traffic noise', HMSO, London,(1988).

Table 1. Minimum areas produced by shaped and rectangular solutions

Noise reduction required dB(A)	Dist. of receptor from road (m)	Area of shaped barrier (m^2)	Area of rectangular barrier (m^2)	Difference (m^2)	Percentage increase
3.8	30	260	270	10	3.9
	60	673	709	36	5.4
	100	1345	1414	69	5.3
5.0	30	425	450	25	5.9
	60	1090	1201	111	10.2
	100	2161	2391	230	10.6
8.0	30	1130	1397	267	23.6
	60	2970	3828	858	28.9
	100	5894	7524	1630	27.7
10.0	30	2030	2798	768	37.8
	60	5675	7950	2275	40.1
	100	10600	17023	6423	60.6

Original noise level 67.8 dB(A), receptor height 3 m above road, distance of barrier from road 6.5 m, ground cover grassland. Very low background noise assumed.

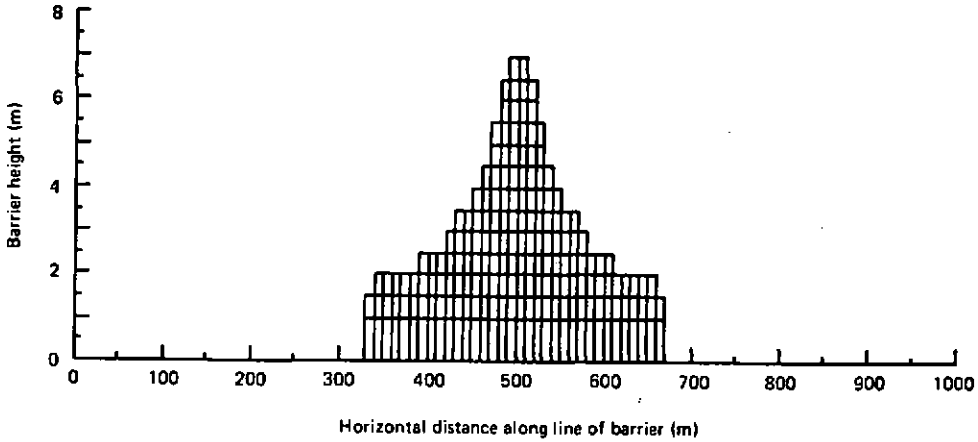

Fig.1 Gaussion-like shape resulting from a screening solution to a single receptor 30m from the carriageway where noise is reduced from 68 to 60 dB(A)

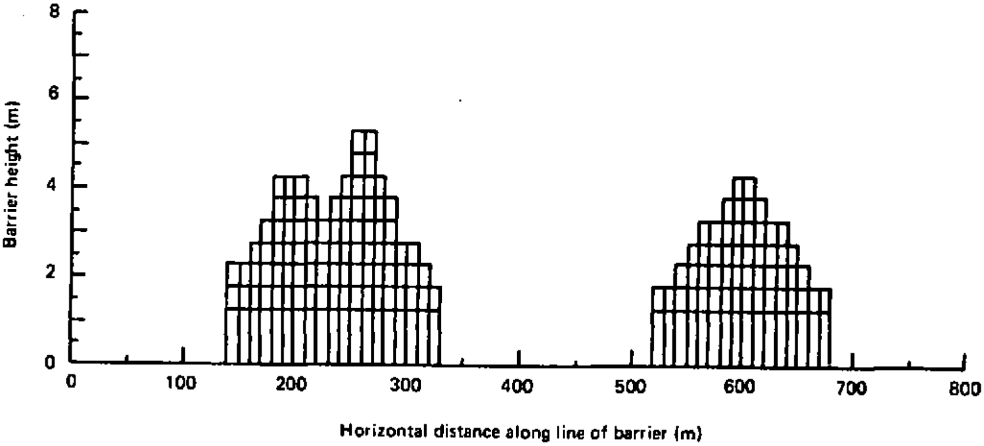

Fig.2 Three receptor problems where two receptors on the right are only 60m apart. Receptors are from left to right 30, 25 and 35m from a road carrying 50,000 vehicles per 18 hr day. The target noise levels are all 67.4dB(A)

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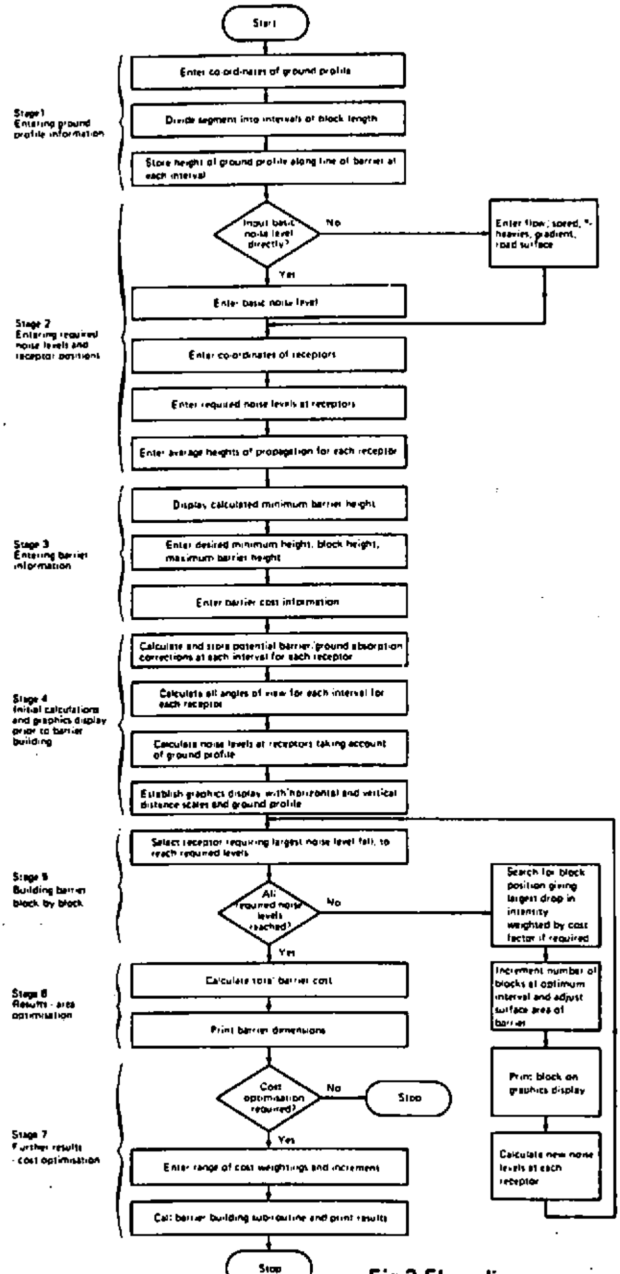

Fig.3 Flow diagram

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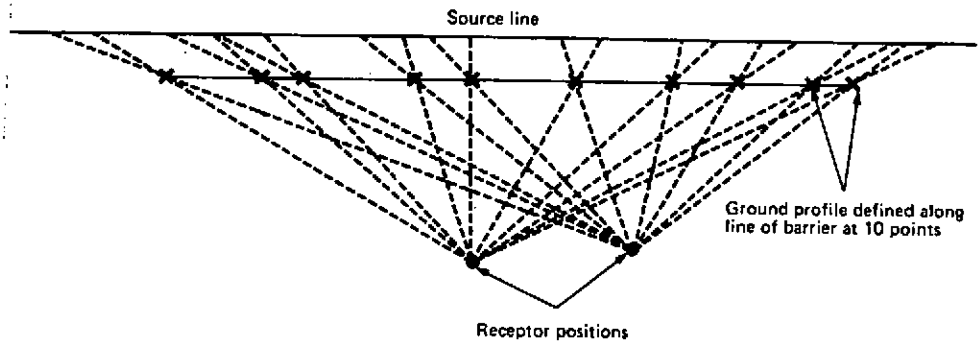

Fig.4 Lines along which the average heights of sound propagation above the ground are calculated for a two receptor problem

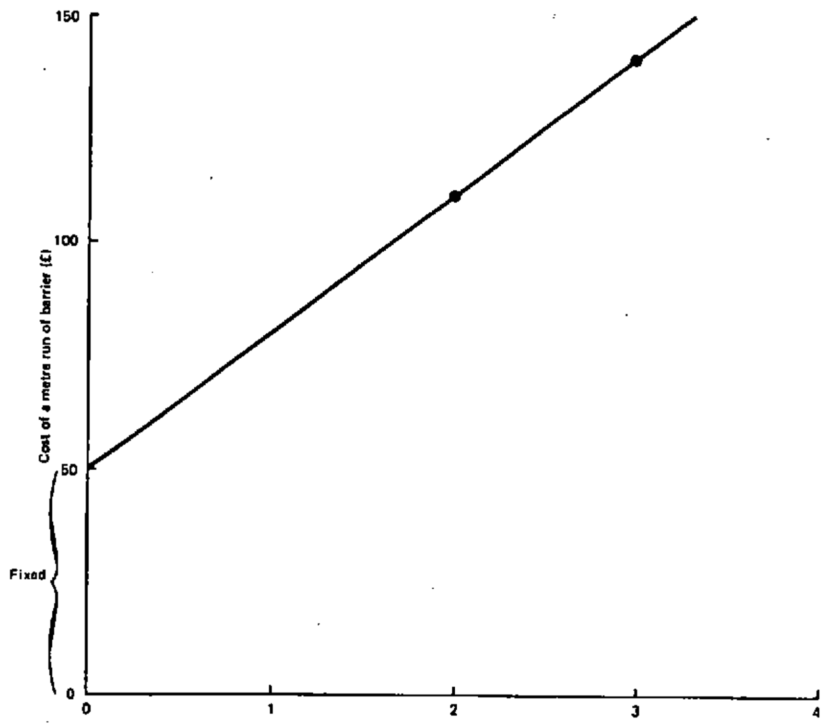

Fig.5 Linear cost model assumed from cost information for 2 and 3m high wooden barriers where cost per metre is not directly proportional to height

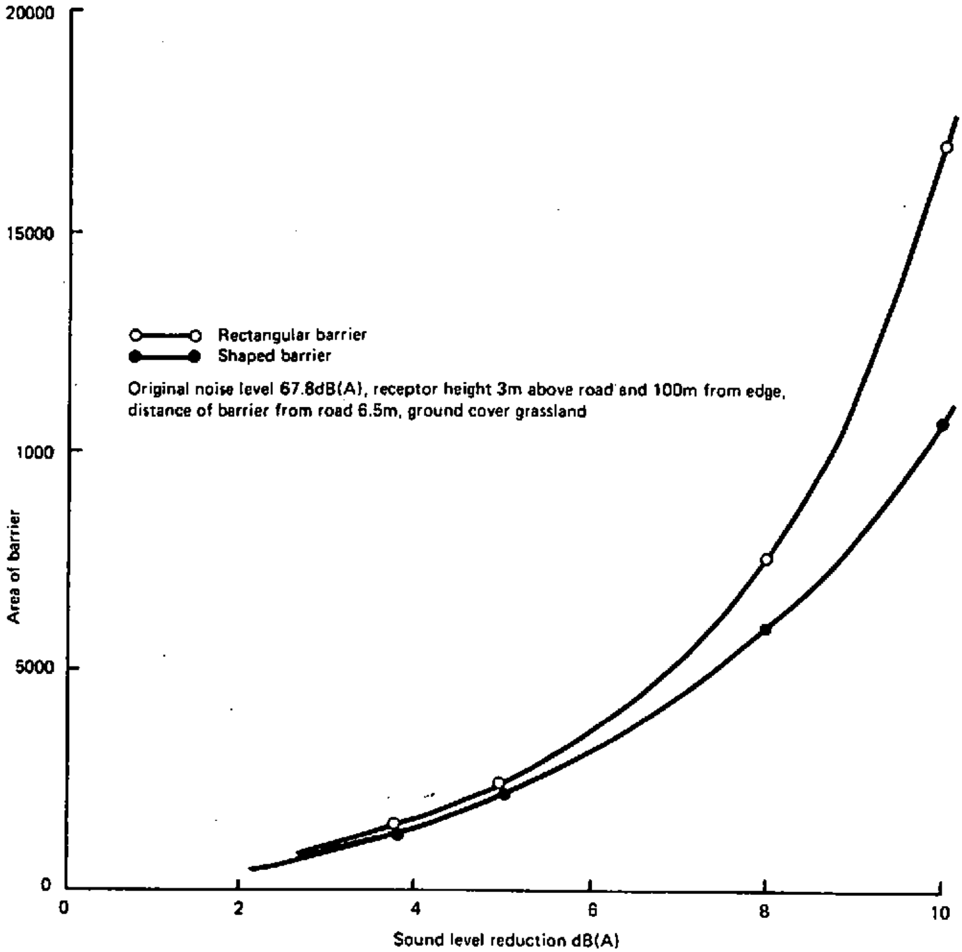

Fig. 6 Barrier areas required to obtain different levels of screening