24th INTERNATIONAL CONGRESS ON SOUND AND VIBRATION
23–27 July 2017, London

TOOLKIT FOR ASSESSING COSTS AND BENEFITS OF NOISE MITIGATION MEASURES

Adam Lawrence, Dan Boote and Inan Ekici

Atkins, The Hub, 500 Aztec West, Park Avenue, Bristol UK, BS32 4RZ
email: adam.lawrence@atkinsglobal.com

The UK Department for Environment, Food and Rural Affairs, Defra, commissioned research to provide practical advice for assessing the costs and benefits of noise control measures for road traffic and railway noise sources. The work was undertaken in the context of noise management areas identified in Action Plans prepared under the Environmental Noise Directive. Approaches to noise control and methods of valuation were reviewed, and a toolkit assessment approach was developed. Advice is given on selecting noise sensitive receptors, selecting noise design targets and scoping noise control options. Lifetime costs are given for measures including purchase, design, approval, installation, maintenance and replacement. Benefits of measures are monetised using the DfT TAG guidance for residential receptors. An overview of other assessments needed is given. The method described gives a consistent approach for assessing the costs and benefits of noise control measures, allowing prioritisation of funds and robust decisions to be made on noise control measures.

Keywords: Noise mitigation, cost benefit analysis, policy, toolkit, costing

1. Introduction

The objective of this paper is to describe an appraisal and evaluation framework for noise mitigation measures which is compatible with Government Policy, and present, with examples, the application of cost benefit analysis (CBA) to noise remediation measures.

The framework described in this paper is derived from work undertaken by Atkins for Defra in 2008-2009 and published in late 2015, Project NANR201 [**1**]. The original work focussed on providing a toolkit assessment process for "management areas" determined from Action Plans prepared under the Environmental Noise Directive (END) [**2**]. Although the work pre-dates several key noise guidance documents the approach remains valid and valuable.

1.1 Assessing Costs and Benefits

As part of Action Plans submitted to the European Commission, the END requires 'cost-effectiveness' and 'cost-benefit' information for proposals on measures and strategies. Therefore an action plan has to balance the 'cost of noise' against the 'cost of tackling noise'. A robust way of evaluating the cost of noise on society provides a useful tool for prioritising cases, helping decision makers compare various actions against one another and justify noise mitigation.

In "The Green Book" [**3**] Her Majesty's Treasury (HMT) provides a best practice guide to the conduct of assessments of projects, policies and programmes. This guidance is binding for government departments and executive agencies. The stated purpose of the Green Book "is to ensure that no policy, programme, or project is adopted without first having the answers to the following questions:

- Are there better ways to achieve this objective?
- Are there better uses for these resources?".

The essential technique advocated by the Green Book is option appraisal. In brief, this comprises: justifying the rationale for government intervention; setting the objectives for the proposed intervention; creating and short-listing potential options for these objectives; and comparing (ideally in monetary terms) the costs and benefits of these options, including wider social costs and benefits. There are various techniques for comparing costs and benefits of options. Cost Benefit Analysis (CBA) is the approach recommended for appraisal in the Green Book.

Recognising one of the disadvantages of CBA, the Green Book also recommends that the approach is proportionate. As a result, it is usual for CBAs to include non-monetised impacts (expressed either quantitatively or qualitatively).

The Green Book is supplemented by guidance in specific areas e.g. the Department for Transport's TAG is used for valuing changes in noise at residential receptors due to road or rail transportation schemes or aviation noise [**4**]. With appropriate robust input data the TAG approach would be applicable to other types of sources and receptors.

2. The Assessment Framework

An appropriate assessment is needed to determine the cost-effectiveness of noise control measures for noise management areas. Such an assessment could be carried out in two stages. A scoping exercise would broadly consider suitable types of noise control measures. A more detailed assessment would subsequently quantify noise reductions and assist the decision-making process.

2.1 Design Targets

The Action Planning guidance in the UK does not set specific design targets for controlling noise. However, when noise control measures are being assessed, and design options are being selecting, it is useful to think about potential noise reductions, and take a view on whether:

- these measures would be suitable for the noise management area; and
- the benefit offered would be significant (i.e. that reductions would be at least perceptible).

For the person assessing the potential noise control options, it is often useful to have a design target in mind, so that they can iteratively adjust the noise control measures to aim towards that target. This also allows demonstration of the overall performance of the control measures and that they serve the purpose for which they were intended. Noise control design targets are not suggested, but such targets would broadly either:

- Aim to reduce noise levels below an absolute noise level or
- Aim to achieve a reduction in noise levels of at least a certain amount.

The design target is simply a tool to determine if the proposed noise control measures are 'fit for purpose' or not. When noise mitigation is being assessed, it may become obvious, for example, that the design target can be met at all but a small number of properties due to the constraints in place. For cost benefit analysis, the reductions in noise levels at the properties is the important result, rather than the design target used to get to that point. The person assessing effectiveness of the noise control measures needs to have a clear idea of what reductions in noise would be "acceptable".

2.2 Assessment Years

The TAG methodology for noise [**4**] uses the concepts of Opening Year (year 0 or the year in which the benefits of the intervention come on line) and future Forecast Year (usually 15 years after opening). Between the Opening Year and the Forecast Year, appraisers are required to use linear interpolation of changes in noise. After the Forecast Year, noise profiles are assumed to remain flat for the rest of the appraisal period since no reliable noise predictions are possible beyond this point.

For Action Plans, the regulations do not provide guidance on the choice of assessment years. However Action Plans need to be revised every five years and this may be a convenient basis for determining the assessment years. For the purposes of CBA of remediation measures, the following assessment years could be adopted:

- Baseline year – the year marking the end of an action planning period, when all planned control measures in that period can be assumed to have been implemented;
- Future year– 60 years after the baseline year, the usual appraisal period for transport investments.

For noise remediation measures, it is reasonable to assume that the 'noise changes' beyond the baseline year will remain constant, unless traffic models are used to predict changes in traffic flows as a result of the noise control measure.

2.3 Scoping

The first step is to undertake a scoping exercise to become familiar with the area, and to identify constraints which may limit options for noise control measures. This approach subsequently enables an accurate assessment of the potential benefits of noise control measures. It is important to identify which noise sources are in the area, and where the noise sensitive locations are.

2.3.1 Noise Source Identification

The strategic noise maps include noise sources at a suitable level of detail for the requirements of the END. In certain situations there may be additional noise sources affecting the local community which have not been included in the strategic noise maps.

The noise control design process should consider these noise sources and their effect on the community. If there are two or more different sources which contribute similar noise levels at a location, then the overall improvement in noise levels will be limited if only one source is mitigated. The noise sources to consider could include roads or railways with flows below the thresholds for strategic noise mapping, or there may be a significant contribution from other transport sources. Also, there may be other types of noise sources which need to be considered in the assessment.

An assessment should be made of the relative importance of all of the noise sources in the noise management area, and a decision made about which ones to include in the noise modelling process.

2.3.2 Noise Sensitive Receiver Identification

When designing noise control measures for a noise management area it is important to consider the sensitive receptors. This will include residential properties and may include non-residential properties which are noise sensitive, for example schools and community facilities. Local knowledge should be able to identify all of the noise sensitive receptors. Separate design targets may be set for residential and non-residential receptors.

Acoustically speaking, the weakest points on the facades of buildings are often the windows, and to a lesser degree, doors.

It is important to accurately consider the number of floors in each building, and to estimate the height above ground level for each floor, particularly when noise barriers are being considered. It is also useful to observe properties which have had loft conversions, as these would usually include bedrooms or other living rooms.

2.3.3 Constraints on Mitigation Measures

At an early stage of the assessment it is necessary to identify suitable mitigation measures which can be meaningfully taken forward for a detailed option assessment. Examples of constraints on mitigation options could include:

- Noise barriers – possibly impractical with access or space restrictions.
- Lower noise road surfaces – typically only beneficial when traffic is moving at higher speeds.
- Improvements to building façade – unlikely to be practicable where there is already non-openable windows and alternative ventilation.

It is also important to note that TAG methodology [**4**] does not directly support the valuation of changes in internal noise levels.

2.4 Scenarios

When assessing potential noise reductions, different scenarios should be considered, so that the noise control measures can be optimised. These could be investigated under ‘Do-minimum’ and ‘Noise Control’ scenarios, each requiring its own design target.

2.4.1 Do-minimum Scenario

The first scenario should be a “Do-minimum” scenario. Here, the noise management area should be reviewed in light of programmed maintenance activities and planned schemes or developments affecting the area. An assessment should consider if these activities or schemes would give rise to changes in noise, which should then be compared with the design target.

2.4.2 Do-minimum Scenario: Design Target Met

If the activities or schemes result in reductions in noise which meet the design target, a review of the proposed maintenance works, schemes and developments should be undertaken to establish which are “certain” and which are “uncertain”, i.e. which are committed schemes (already planned and funded), and which are not committed (subject to further planning or funding, or are dependent on some other external constraints). This review effectively determines the level of risk that these works/schemes/developments go ahead and deliver the resultant improvement in noise levels.

If the design target is met, then other noise control measures do not need to be designed, and this can be reported. The noise control strategy becomes re-programming existing planned activities, and potentially supporting schemes or developments which contribute to the improvement in noise levels.

2.4.3 Do-minimum Scenario: Design Target Not Met

If the activities or schemes result in increases in noise, or reductions in noise levels which are below the design target, then further noise control measures are required. The noise control measures should then be based on the Do-minimum situation, so that the overall noise targets can be met.

2.4.4 Noise Control Scenarios

To identify suitable noise control measures, it is useful to consider at least two different noise control scenarios. The first scenario could have a tightly focussed design target, perhaps to offer a small reduction in noise at a few properties. The second scenario could have wider aims to offer greater reductions in noise or to consider greater benefits at a number of properties. By adopting two scenarios in this manner, it is possible to compare two different levels of spend on noise control measures and to compare them with their relevant benefits.

2.4.5 Focussed Noise Control Scenario Example

For a focussed scenario example, the design target could be to reduce the noise levels by a small amount at the worst affected properties. The noise control measures could be designed to give at least a 3dB reduction in noise levels at those buildings with the highest noise levels. Specifying a reduction in noise greater than 3dB would be desirable.

2.4.6 Broader Noise Control Scenario Example

For a broader scenario example, the aim could be to reduce noise levels to below a specific noise level at all properties within the noise management area. The scenario should recognise that in some places this may not be easy to achieve, and in these situations the aim should be to provide as large a reduction in noise as practical.

2.5 Study Area

Once the scenarios and targets have been defined, it is important to ensure that an appropriate study area is defined. The study area should include all properties where changes in noise of 1dB or greater are expected. In practice, the study area should be extended slightly further than this to include properties where the change in noise is less than 1dB and to positively demonstrate the extent of the study area.

The toolkit [**1**] provides information on likely study area sizes for different noise control measures:

- Noise levels below 55dB not usually needed when considering mitigation for receptors with noise levels well over 60dB
- Study area unlikely to extend beyond 800m from the source, and is usually within 400m.
- For barriers, 3dB reductions are usually within 200m of the source.

If the assessment shows that a larger study area is required, then this should be adopted in order to assess all of the changes in noise equal to or greater than 1dB.

2.6 Costs of Noise Control Measures

It is necessary to estimate the costs of each noise control measure being considered. The toolkit provides advice on the steps that need to be undertaken. Chapter 6 of the report [**1**] gives a description of methods available for controlling noise and approaches for assessing potential benefits. Chapter 7 provides indicative costs for key noise control measures:

- Rail grinding and wheel turning (rail);
- Rail pad replacement (rail);
- Alternative road surfaces (road);
- Altering traffic flow (road);
- Imposing vehicle restrictions (road);
- Speed restrictions (road);
- Noise barriers (road and rail);
- Building envelope improvements (road and rail).

Costs were identified based on Atkins project experience and selected references. For noise barriers costs were principally found in TRL report PPR047 and costs for road surfaces were principally from SPON's Price Book, which is updated annually.

Cost allowances were made in percentage terms for design, approvals, traffic management, risk, and other costs, and the process includes for routine maintenance and replacement costs over the 60 year appraisal period.

2.7 Value of Noise Changes

Suitable monetary values of noise changes are needed for the cost benefit analysis. The recommendation in Chapter 8 of the report [**1**] is to monetise changes in noise at residential receptors using the TAG guidance [**4**].

2.8 Non-acoustic Assessments

The toolkit also provides advice on what other assessments may be required for the noise control measures. These would need to be undertaken, and the results summarised for the cost benefit analysis. Chapter 9 of the report [**1**] gives advice on other assessments that may be required including: Air Quality, Ecology, Cultural Heritage, Landscape and Visual Effects, Community Effects, Flood Risk and Drainage, Water Quality and, Geology and Soils. Advice also covers requirements for planning and building control.

2.9 Cost Benefit Analysis

The results of the noise assessment need to be brought together with the costs of the noise control measures being considered, and the results of any non-acoustic assessments undertaken. Overall, the process should optimise the net benefits, and each scenario should be examined individually to ensure that this is the case. It may be appropriate to undertake a number of iterative calculations so that the optimum benefits can be determined, within the constraints of the scenario. Iterations may involve changing the scale or type of noise control measure, re-defining the study area or selecting a different design target for the scenario.

3. Valuation and Discounting

The guidance in TAG [**4**] explains in detail the steps required to value a change in noise. An example valuation calculation is given below to illustrate the main steps. Further details of this calculation are provided in NANR201 [**1**], Chapter 8, with supplementary data in Appendix C of the report, although it is noted that the version in the report uses an earlier version of the TAG monetisation than the example shown here:

3.1 Noise Benefits Calculation

Table 1: Calculation of Noise Benefits

Step	Details
1	Work out the willingness to pay for the change in noise in the opening year. Example: As the result of a noise control measure road traffic noise in 2020 levels drop outside a property from 71dB L_{Aeq} to 67dB L_{Aeq}, a reduction of 4dB. Night time levels are assumed to be 6dB lower than daytime levels. The monetary value of this change, including sleep disturbance, in 2014 prices, is £553.31.
2	Repeat this for any other future assessment years being considered. For this example, we suppose that an assessment has been carried out 10 years after the measure, showing traffic growth giving rise to a 1dB increase irrespective of the scheme. Therefore, in the 10th year, the assessment of the measure would show a 4dB reduction of noise from 72dB L_{Aeq} to 68dB L_{Aeq}. The monetary value of this change, in 2014 prices, is £581.92.
3	Use linear interpolation to value changes in noise between the assessment years. In this example, the benefit in Year 0 is £553.31, and the benefit in Year 10 is £581.92.
4	Assume that noise levels do not change after the last assessment year. Therefore the monetary value in 2014 prices, is £581.92 in Year 11 through to Year 60.
5	Identify growth factors for the actual years. For each year this is the multiplication of all growth factors for all years between 2014 and the year in question.
6	Discount the benefits in line with the values in the Green Book [**3**]. No discount is applied in the first year of the assessment, but each subsequent year is discounted by the appropriate discount rate, so after 1 year the discount factor is 1 minus 3.5%, and after 2 years the discount factor is 1 minus 3.5% twice.
7	Overall, the benefits must be growthed and discounted, so the benefit in each year is multiplied by both the growth factor and the discount factor for that year. Sum the results over the appraisal period. The total over the 60 year appraisal period for this example is £22,117. This figure is the economic benefit for one household, and the process would need to be repeated for all of the other residential properties being considered.

The 2015 version of TAG provides the distribution of the different health benefits arising from the changes in noise. The analysis for this example shows that over half of the benefit comes from reduction in sleep disturbance, and over a quarter comes from reduction in annoyance. Reductions in health impacts: acute myocardial infarction, stroke and dementia comprise the remaining 15% of the benefit.

3.2 Valuing costs of mitigation measures

For the costs associated with noise mitigation measures, the following steps are required to identify the net present value.

Step 1: identify the costs of the noise control measure and identify the maintenance schedule. Let us suppose that a 200m long, 3m high timber barrier is being considered beside a road.

Table 2: Costs of the noise control measure

Item	Cost allowance	Cost
Timber barrier (£210/m from Table 7.3)	N/A	£42,000
Highway Authority Approvals	10%	£4,200
Design Costs	12%	£5,040
Traffic management	20%	£8,400
Protection	10%	£4,200
Risk/Contingency	10%	£4,200
Total Costs		£68,040

Let us suppose that maintenance is required every 10 years at 10% of the supply costs, and that the barrier requires replacement every 20 years. The replacement barrier would not require planning approvals or design costs, but it has been assumed that traffic management and replacement barrier protection was required.

Table 3: Costs of the maintenance activities

Item	Cost allowance	Cost
Maintenance Costs (Every 10 year)	10%	£4,200
Replacement timber barrier (Every 20 years)	N/A	£42,000
Traffic management for replacement works	20%	£8,400
Replacement protection (Every 20 years)	10%	£4,200
Total Costs – Maintenance (Every 10 year)		£4,200
Total Costs – Replacement (Every 20 years)		£54,600

Step 2: Set out the costs of the noise control measure.
Step 3: Discount the costs in line with the values in the Green Book [**3**].

Table 4: Discounted maintenance costs

Year	Activity	Cost	Discount factor	Discounted Cost
0	New Barrier	£68,040	1.00000	£68,040
10	Maintenance	£4,200	0.70892	£2,977
20	Replacement	£54,600	0.50257	£27,440
30	Maintenance	£4,200	0.35628	£1,496
40	Replacement	£54,600	0.26510	£14,474
50	Maintenance	£4,200	0.19726	£828

Step 4: Sum the discounted costs over the appraisal period to give the economic cost. The total economic cost of this noise control measure is £115,257. For this particular maintenance and replacement programme, the economic cost is seen to be approximately three times the initial cost of £42,000.

3.3 Cost Benefit Analysis

With the two examples above, it is possible to undertake a comparison of the costs and benefits. If we assume that the barrier is required at roadside, then the economic costs of the measure are £115k. The economic benefits for this measure were shown to be £21k for one property, and therefore, if the measure were providing the same benefits at more than 5 properties, and assuming that no other costs or benefits were incurred, then the benefits of the measure would outweigh the costs. This comparison provides the Net Present Value (NPV) of the measure, as shown in the following table.

Table 5: Example Net Present Value

Measure provided at number of properties	Economic benefits from reduction in noise	Economic cost of noise control measure	Net Present Value
1	£22,117	£115,257	-£93,158
5	£110,585	£115,257	-£4,690
6	£132,702	£115,257	£17,427
10	£221,170	£115,257	£105,895

The costs of noise barriers depends on the situation. If the barrier can be installed during other routine maintenance works in the area then the initial costs may be reduced, whereas if it were installed on a structure rather than at roadside the initial costs would be higher.

3.4 Road surfaces

A similar approach can be followed for the use of quieter road surfacing. However, since roads need to be re-surfaced as part of routine maintenance, the cost of the measure is the difference between the cost of maintaining the existing road surface compared with the cost of maintaining the new road surface. A Thin Wearing Course has a shorter design life than a Hot Rolled Asphalt (HRA) surface, and therefore resurfacing would be required more frequently.

The report [**1**] shows that if a HRA surface has a 15 year design life and a Thin Wearing Course has a design life of 12 years, the economic cost of resurfacing would be approximately equal to the cost of the initial cost, including planing the existing road surface during works.

4. Guidance Updates

The process described in this paper is in line with new documents and revisions to existing documents published since the publication of NANR201[**1**]. New documents include the 2010 Noise Policy Statement for England, and the 2011 World Health Organisation Burden of Disease from Environmental Noise. Updates include the 2011 noise chapter of the Design Manual for Roads and Bridges, and the 2015 Transport Appraisal Guidance Unit A3[**4**]. There have been subsequent rounds of strategic noise maps and action plans, and more assessment consideration of lower noise surfaces.

5. Conclusions

This paper has described an appraisal and evaluation framework for noise control measures compatible with current UK Government Policy. The paper is derived from work undertaken by Atkins for Defra and published in report NANR201 [1] where more detail, examples and a toolkit for assessment can be found. The method described gives a consistent approach for assessing the costs and benefits of noise control measures, allowing prioritisation of funds and robust decisions to be made on noise control measures.

REFERENCES

1 Atkins, *Defra NANR 201 – Environmental Noise Valuation – The Costs and Benefits of Remediation Measures*, (2011). Online through http://randd.defra.gov.uk

2 *DIRECTIVE 2002/49/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 June 2002 relating to the assessment and management of environmental noise*, (2002)

3 *The Green Book, Appraisal and Evaluation in Central Government*, H.M. Treasury, 18 April 2013 (updated 11 November 2016)

4 *WebTAG, TAG Unit A3, environmental impact appraisal*, December 2015, Department for Transport.