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ALTERNATIVES TO UK NOISE INSULATION REGULATIONS

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As a result of the Action Plans emerging from the Strategic Noise Maps of England, Highways England have to investigate and provide mitigation options at Important Areas in England. Work was commissioned to investigate options to improve the health and wellbeing of people adjacent to the road network where it is either impractical or not cost effective for roadside noise mitigation or lower noise surfacing. The work focussed on those properties which are in Important Areas adjacent to the Highways England road network. A number of options were developed with acoustic and ventilation solutions to meet Building Regulations and acoustic design targets, and a preferred option was identified. Costs, benefits, maintenance issues and equipment life expectancy were identified and an outline business case presented, showing a benefit-cost ratio of 1.6:1, representing a value for money solution. A number of constraints were identified including certain building constructions and potential for overheating. Costs were generally shown to be around £6000 per property, replacing existing glazing with a double glazed solution and with the provision of ventilation. This approach could be used for similar properties in the rest of the UK, near Local Authority roads or near the rail network.

Keywords: Noise Insulation, Road Traffic Noise, Economic Appraisal, Ventilation, Mitigation

1. Introduction and Scheme Objectives

The Environmental Noise Directive requires Action Plans to be prepared which identify important areas and describe actions that will be taken. The important areas in England are those where noise levels are the highest. These are properties which are among the worst affected by noise, and the people who live there have the greatest adverse health impacts. Highways England is responsible for investigating the important areas adjacent to its network and providing mitigation, and is currently able to use two mitigation measures; resurfacing the road with a lower noise surface, and installation of noise barriers (or similar screening measures) adjacent to the road.

For larger areas it is often cost effective to mitigate noise levels with these measures, but costs often mean that the measures are not cost effective at smaller areas with few properties.

This paper describes work undertaken by Atkins to establish a scheme allowing measures to be installed at 1,016 important areas in England which each contain fewer than 10 properties where the current mitigation measures have been shown not to be cost effective. Overall the scheme would apply to 2,967 residential properties. The schemes objectives are:

- To improve the health and well-being of people in these areas through mitigation
- To apply cost effective investment to those properties worst affected by traffic noise.

Highways England does not offer noise insulation at properties outside the remit of the Noise Insulation Regulations [1]. The flexibility to have a noise insulation option in the Highways England portfolio would allow mitigation to be provided at locations where it is either not cost effective or not practical to use the described currently available mitigation measures.

2. Important Area Housing Details

Approximately one third of the important areas being considered for this study have just one property in them, and one fifth of important areas have two properties in them. In total more than two thirds of the important areas have three or fewer properties.

The majority of the properties are outside urban areas. The English Housing Survey, 2008 Housing Stock Report [2], indicates the following relevant factors:

- Properties near major roads tend to have been built before 1944 and are likely to be of traditional bricks and mortar construction.
- Some 40% of properties near major roads have made alterations to increase living space.
- There are around 10% of properties across England with some living space within the roof construction, either by original design or by conversion.
- Around 25% of properties have single glazing or a mix of different glazing types.
- Around 16% of properties have a conservatory, and of these, 92% have a door separating the conservatory from the rest of the property.
- The average useable floor area for properties in England is 91m^2. Detached and semi-detached houses in the private sector have the greatest floor area, with 40% having floor area exceeding 110m^2. 40% of houses have a floor area less than 70m^2.
- Bungalows make up some 9.4% of properties, but these tend to be smaller with around 15% having areas over 110m^2 and 70% having an area less than 70m^2.

3. Health Impacts

3.1 Noise – Sleep Disturbance

Research shows a range of health effects arising from exposure to noise. Relationships exist to evaluate and monetise the health effects of exposure to noise, including sleep disturbance, which are based on external noise levels. These are described in the Department of Transports Transport Appraisal Guidance documentation, Unit A3 [3] (TAG).

As a noise insulation scheme would only affect the internal noise levels, it is necessary to consider which health effects can be robustly assessed. It is reasonable to develop a relationship to assess the benefits on sleep disturbance. This is a time period when most people can be reasonably assumed to be inside their properties, and therefore is a robust way of measuring the resulting health benefits.

To achieve this it is necessary to develop a relationship which allows the benefits from improvements to internal night time noise levels to be evaluated. A proxy external noise level is used to represent the situation with the measures in place.

3.2 Ventilation and Other Noise Impacts

Improvements in internal noise would also give rise to improvements in other health indicators; decreases in annoyance and in the risk of Acute Myocardial Infarction (AMI), stroke and dementia.

The provision of ventilation measures in the properties is also likely to improve the internal conditions with potential for health and well-being benefits. The benefits could include reducing draughts, providing fresher air, reducing potential for mould growth, and so on.

In undertaking a proportionate economic assessment of the scheme the focus has been on the key measureable impact, reduction in sleep disturbance. The other benefits are difficult to measure and monetise, and have been excluded from the assessment.

4. Acoustic Criteria

The most relevant document with recommended internal noise levels for dwellings is the British Standard BS8233: 2014 [4]. This standard recommends that noise levels should be limited to 30dB

$L_{Aeq,\,8hr}$ in bedrooms at night and at 35dB $L_{Aeq,\,16hr}$ in bedrooms and living rooms during the day. Guideline daytime noise levels in dining rooms are 5dB higher than for living rooms.

To achieve the acoustic targets, it is necessary to ensure that external noise levels are attenuated sufficiently through the structure of the building, and this is achieved by focussing on the elements of the construction with the lowest acoustic performance. For dwellings of a traditional bricks and mortar construction, this is most likely to be the glazing/windows and any ventilation provisions.

If the property has sections built of a lighter construction, with sufficiently high external noise levels, the acoustic performance of this lighter construction may be a limiting factor in reaching the target acoustic levels. This is particularly true with dormer roofs and conservatories.

Similarly, the acoustic performance of the ventilators can be the determining factor at the higher external noise levels as there is a limited range of products with the highest acoustic performance. The ventilator performance requirements are also dependent on the size of the window.

The scheme is not viewed suitable for caravans, houseboats and other portable homes or very lightweight forms of construction as the noise reduction through the structure of these types of property is likely to be the limiting factor.

Using the recommended internal noise levels of BS8233, noise insulation measures are targeted at the following noise sensitive rooms within properties:

- Bedrooms
- Living/Reception Rooms
- Dining rooms/areas,
- Studies

Bathrooms, toilets, hallways/landings, utility rooms and kitchens without dining areas are not considered to be noise sensitive, and are therefore not included for noise insulation measures.

5. Ventilation Criteria

The provision of ventilation in dwellings is governed by the Building Regulations, and the requirements are described in Approved Document F, 2010 [5]. The essential requirement is that when modifications are made to existing buildings the ventilation should not be made any worse.

The Approved Document provides required ventilation rates for new dwellings and for when extensions are added or certain works are carried out to existing buildings. The rates are set to achieve rapid extraction of water vapour and hazardous pollutants and to provide a supply of outdoor air.

For properties in England, there is often a requirement for additional ventilation in the summer months when outdoor temperatures are higher. The traditional approach is to open windows and allow excess heat to be purged from the property. This approach, however, allows external noise in through the open window with the consequence of increase internal noise levels, and potential health impacts.

In order to reach the internal noise targets, windows need to be kept shut and alternative ventilation provided. The inclusion of additional ventilation to deal with purging heat whilst leaving windows closed would present an additional cost to the design.

5.1 Ventilation Systems

Approved Document F describes four types of ventilation system to provide adequate ventilation in a property. The four systems are referred to as systems 1, 2, 3 and 4. Of these systems, system 2 – Passive Stack Ventilators (PSV) - has been discounted from further consideration as it is difficult to develop into a generic solution. The three other systems, being taken forward, are described below.

5.2 Background Ventilation

This system is System 1 in Approved Document F. It provides background ventilation to all habitable rooms. Intermittent extraction fans are installed in bathrooms, toilets, kitchen and utility rooms. In order to provide good ventilation throughout the property there is a 10mm gap between the bottom of each internal door and the floor finish. This gap is known as an undercut.

The background ventilation requirements differ between older properties and newer properties, with greater equivalent area requirements for the newest properties. The ventilation rates are higher for bungalows than they are for houses of more than 1 storey.

5.3 Continuous Extraction

5.3.1 Decentralised Fans

This system is System 3 in Approved Document F. It is like the background ventilation system described in Section 5.2 with background ventilation in habitable rooms, extraction fans in bathrooms, toilets, kitchens and utility rooms and a 10mm undercut on all internal doors.

The difference is that the extraction fans run continuously. Because of this there is a constant flow of air drawn through the property, and the area of each of the ventilators in the habitable rooms can be smaller, and the system can therefore be used in areas with higher noise external noise levels.

5.3.2 Centralised Fans

A variation on this system is to install a centralised extraction fan. This requires duct runs within the property from the bathrooms, toilets, kitchen and utility rooms to a central point where the fan would be located. A vent in each room would normally be mounted in the ceiling.

Requirements for background ventilation and undercuts remain as for the decentralised fan option.

5.4 Continuous Supply and Extraction

This system is System 4 in Approved Document F. It installs a central fan to the property which provides an air supply to each habitable room and an extract from bathrooms, toilets, kitchen and utility rooms. Each room is connected to the central fan with a duct run, with a supply or extract vent in the ceiling. The system would run continuously and provide the best internal conditions.

Because each room has either a supply or an extract there is no need for there to be background ventilation in any room, and the system can be used in any external noise levels.

As the fan deals with both the supply and extraction of air in the property the system can incorporate a heat exchanger to reduce energy requirements of the heating of the property during the winter, and result in the lowest overall running cost for the property.

6. Design Process

6.1 Glazing Specification

The majority of dwellings in England have double glazed windows in uPVC frames. In order to meet the internal noise levels described in Section 4, it is necessary to replace low specification glazing with units that have a particular acoustic performance. The acoustic performance of windows is specified as the Sound Reduction Index R_w, which is a single figure number characterising the airborne sound insulating properties of a material or building element over a range of frequencies, measured under laboratory conditions. Meeting the glazing specification can be achieved either with double glazed units or by the use of secondary or triple glazing. The actual specification needed will principally depend on four factors:

- The noise level outside the window
- The desired noise level within the room
- The area of the window.
- Ventilation requirements.

6.2 Ventilator Specification

The majority of dwellings in England use trickle vents in their windows to provide background ventilation. In order to reduce the internal noise levels to levels which meet the targets described above, it is necessary to ensure that the ventilators used are replaced with units that have a particular

acoustic performance. The acoustic performance of ventilators is described with the weighted element normalised level difference $D_{n,e,w}$, which is a single figure number characterising the sound insulation properties of a small building element. This unit uses a standard approach to allow a comparison of the acoustic performance of products, as measured in a laboratory.

Meeting the acoustic performance of the ventilation system can be achieved either with replacement trickle vents or by the use of wall vents which may be ventilators or air-bricks. The acoustic specification of the products needed will principally depend on four factors:

- The noise level outside the window
- The desired noise level within the room
- The equivalent area requirements for the ventilation.
- The acoustic performance of the window.

6.3 Design Process

Bringing the glazing and ventilation factors together sets out a design process. For each room it should be possible to determine a combination of glazing and ventilation products which allow the internal noise targets to be met. The process first needs to quantify;

- External noise level
- Internal noise target
- Window size(s)
- Ventilation requirements

There are two values to be determined, the R_w of the glazing/window(s) and the $D_{n,e,w}$ of the ventilation product(s). It is necessary to consider the worst case situation and the external $L_{A10,18hr}$ needs to also be converted into an L_{night} level [6]. In the case of properties adjacent to motorways, the night time noise criteria is most stringent, and for properties by A-roads the daytime target is most stringent. The performance to meet the daytime target in a property next to an A-road would be some 1-2dB lower than to meet the motorway night time target. The target is then expressed in terms of the R_w for the glazing. The other aspect is the requirement for ventilation. Ventilators with an appropriate $D_{n,e,w}$ performance may or may not be required, depending the age of the building and any existing means of ventilation.

7. Review of Technical Options

There are essentially three technical options available for achieving the required noise insulation performance and provision of adequate alternative ventilation. These options comprise the combination of the single acoustic solution with each of the three ventilation solutions.

There are a number of minor variations available with the ventilation systems. For ventilation systems with background ventilation (Approved Document F System 1) background ventilation could be provided the through vents in the windows or through vents in the walls. For the continuous extraction system (Approved Document F System 3) the extraction can either be provided centrally or distributed through the property. Overall, there are nine options considered, shown in Table 1.

Where dwellings are exposed to the highest noise levels it is unlikely that ventilators with sufficiently high acoustic performance are available, which discounts background ventilation options (1 to 4) and a continuous extraction option (5 to 8) could be used – shown in the “Option With High Noise Levels” column in Table 1.

For dwellings with the very highest noise levels the continuous extraction options (5 to 8) are also discounted due to the unlikely availability of ventilators with sufficient acoustic performance. A centralised system with both supply and extract (Approved Document F System 4) would be needed in this situation (option 9) – shown in the “Option With Very High Noise Levels” column in Table 1.

Table 1 - Summary of Technical Options

Option	Option Description	Option With High Noise Levels	Option With Very High Noise Levels
1	Window vents, intermittent extraction	Option 5*	Option 9+
2	Wall vents, intermittent extraction	Option 6*	Option 9+
3	Window vents, intermittent extraction[1]	Option 7*	Option 9+
4	Wall vents, intermittent extraction	Option 8*	Option 9+
5	Window vents, continuous distributed extraction	Option 5*	Option 9+
6	Wall vents, continuous distributed extraction	Option 6*	Option 9+
7	Window vents, continuous centralised extraction	Option 7*	Option 9+
8	Wall vents, continuous centralised extraction	Option 8*	Option 9+
9	Centralised supply/extraction with heat recovery	Option 9*	Option 9+

* Potential for increased acoustic performance on windows and/or ventilators

+ Likely need for increased performance on windows

The noise level threshold for changing the ventilation solution will depend on the particular acoustic performance of the glazing and ventilation products being considered.

8. Cost Benefit Analysis

A range technical solutions have been designed to meet the scheme objectives. To determine the option with best value for money, a shortlist of options has been taken forward for economic appraisal.

8.1 Scope of Works

The total costs for a property depend on the amount of work that is done. Five basic approaches could be followed for undertaking the works:

- Scope A: Works to all rooms
- Scope B: Works to all rooms – non-noise sensitive rooms get standard glazing, noise sensitive rooms below the noise criteria get appropriate glazing.
- Scope C: Works to all noise sensitive rooms
- Scope D: Works to all noise sensitive rooms, those below the criteria get appropriate glazing.
- Scope E: Works to noise sensitive rooms which exceed the criteria

8.2 Property Cost Estimates

It is necessary to compare the costs of the works for the different scopes of work and technical options described above. The table below shows the cost estimates, in 2016 prices, for one property with external noise levels sufficient that all technical options can be implemented.

The costs are estimated for an example property, an un-extended 1930's semi-detached house with 3 bedrooms and 2 reception rooms. The property is assumed to have 28m^2 of glazing, split with 6m^2 in non-noise sensitive rooms and 22m^2 in noise sensitive rooms. The noise sensitive rooms are and split with 12m^2 on the side of the property facing the road and 10m^2 on the opposite side. A number of important exclusions and assumptions have been made in estimating the costs. The main areas of uncertainty for the assessment of costs and benefits are;

- Simplifying assumptions in the design process leading to over-design or under-design
- Issues at specific properties leading to increased installation costs

[1] Options 3 and 4 differ from Options 1 and 2 on the basis of the options used in High Noise Level conditions only

Table 2 - Single Property Cost Estimates, £

	Scope A	Scope B	Scope C	Scope D	Scope E
Option 1 & 3	£12,051	£11,139	£10,603	£9,690	£6,697
Option 2 & 4	£13,710	£13,259	£12,261	£11,972	£7,565
Option 5	£10,815	£9,903	£9,367	£8,455	£6,040
Option 6	£10,453	£10,003	£9,005	£8,716	£6,302
Option 7	£12,900	£11,988	£11,425	£10,539	£8,126
Option 8	£12,538	£12,088	£11,090	£10,801	£8,387
Option 9	£13,923	£13,472	£12,571	£12,121	£9,869

Scope A has the highest cost and Scope E has the lowest cost. Options 5 and 6 cost approximately the same and are the options costing the least. Options 7 and 8 also cost approximately the same. The most expensive option is Option 9, although this is only marginally more expensive than Options 2 and 4. Costs would be greater where higher noise levels are encountered.

It is important to consider the proportion of properties that would take up the offer of works. Assuming a 100% take-up of the scheme, and assuming that 3.5% of properties (based on distribution of strategic noise mapping data) have higher noise levels, and therefore higher costs, total scheme costs for these options and scopes range between £18.3m and £41.5m in 2016 prices.

Older properties are unlikely to require the full ventilation option included in these costs. Larger properties are likely to have more noise sensitive rooms and require additional works. Based on the information available it is estimated that the total cost could be £2.7m lower for reduced ventilation requirements and the total cost could be £3m higher for larger properties, both in 2016 prices.

8.3 Scheme Benefits

Scope of works A, B, C and D provide treatment to all noise sensitive rooms, and the monetary value of the reductions in noise can be applied in full to properties where these scope of works are used. The value of health impacts of reduced sleep disturbance in these situations is estimated to be £46.1 million (PVB, 2010 prices and values over a 25 year appraisal period from 2018).

However, with Scope of Works E the treatment is restricted to noise sensitive rooms which exceed the criteria, and therefore are likely to be applied only to façades of properties which face the road. An initial estimate of the reduction in benefits is obtained by assuming that two bedrooms face the road and would be treated, and one bedroom is on the opposite side and would not be treated. Therefore, the monetary value is reduced by 1/3, giving a revised value of health impacts due to reduced sleep disturbance of approximately £30.7 million (PVB, 2010 prices and values over a 25 year appraisal period from 2018).

It is also noted that treatments are provided for other noise sensitive rooms (living rooms and dining rooms) even though these are not included in the monetisation of the benefits.

8.4 Option Selection

There are a number of factors and risks associated with each option. These have been considered and ranked in order to develop a short-list for economic appraisal in an Outline Business Case;

- Operationally, option 9 is the preferred option.
- From an installation perspective options 1, 3 and 5 are preferred.
- From a running costs perspective, option 9 is the preferred option.
- From a maintenance cost options 5 and 9 are preferred
- From the scope of works, it is Scope B which is preferred.
- From the cost of works perspective, it is Scope E which is preferred.

This gives four technical options (1, 3, 5 and 9), and two scope of works options (B and E), giving 8 options in total.

A cost benefit analysis was undertaken for each of these options to determine which performed best in terms of value for money. The results are presented in Table 3.

Table 3 - Summary of Cost Benefit Analysis for Shortlisted Options (all Scope B and E), £ million, 2010 prices and values, discounted over 25 year appraisal period

£ million, 2010	**Option 1B**	**Option 3B**	**Option 5B**	**Option 9B**	**Option 1E**	**Option 3E**	**Option 5E**	**Option 9E**
Householders								
Noise benefits	46.1	46.1	46.1	46.1	30.7	30.7	30.7	30.7
Renewal costs	7.2	7.2	3.9	4.0	7.2	7.2	3.9	4.0
Highways England								
Implementation costs	30.2	30.3	26.9	36.4	18.3	18.4	16.6	26.8
Overall Metrics								
Net Present Value (NPV)	8.7	8.6	15.2	5.6	5.2	5.1	10.2	-0.1
Benefit-Cost Ratio (BCR)	1.29	1.28	1.57	1.15	1.28	1.28	1.61	1.00

The preferred business case option based on the assessment of costs and benefits is Option 5 (Window vents, continuous distributed extraction) with Scope of works E (Works to noise sensitive rooms which exceed the criteria). This option has significantly lower cost than Option 9 which otherwise scores well in terms of operational performance and maintenance costs. The higher costs associated with Option 9 mean it represents lower value for money than Option 5E.

9. Conclusions

The overall cost of option 5E in 2016 prices is £18.3 million, with an NPV of £10 million and a BCR of 1.6:1. This option was recommended as the preferred option, representing a value for money solution for Highways England based monetised costs and benefits. This is a conservative estimate as it does not capture a range of non-monetised benefits that would enhance the case for investment.

The economic appraisal suggests a clear and compelling case for progressing the scheme, which provides a viable cost-effective way of delivering positive health outcomes and a raised quality of life for those living adjacent to the road network.

REFERENCES

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