APPENDIX A1.1 – DRAFT BEST PRACTICE GUIDELINES FOR THE MEASUREMENT OF GROUND BORNE NOISE FROM TRAINS

CONTENTS

1. Introduction

The purpose of this best practice guideline document is to provide advice on the investigation of complaints of ground borne noise from trains and ensure as far as possible that all measurements are conducted in the same manner. These guidelines are designed to be suitable for those acting on behalf of either the complainant and/or the railway operator. Such guidelines are especially useful where it is necessary to repeat measurements (for example following remedial action)) or to allow "the other side" or an independent to make an objective assessment.

The best practice contained in this document is formed from an MSc dissertation[1] in the subject and incorporates the author's experience, the results of an extensive literature search and the experience of other practitioners on the field obtained through an in-depth questionnaire survey. The rationale behind the choice made in this guidance document is given in the main body of the MSc dissertation.

Much of the following document is common sense, but it is nevertheless important to take into consideration. Note this draft version does not contain any limit values, information on this subject is given in the dissertation.

2. Justifying the Need for Measurements

Where ground borne re-radiated noise and vibration complaints occur it is often necessary to arrange a visit to the property so that noise (and vibration) measurements can be made. This work is beneficial to:

- Assess the severity (and validity) of the complaint.
- Provide an objective measurement of the noise and vibration levels to verify or refute the complainant's subjective view.
- To assist in determining the source(s)[2] of the complaint
- Provide evidence to show whether it is a deteriorating or modified railway condition or a change at the receiver location.
- To provide a baseline against which improvements can be assessed.

3. Before Measurements are undertaken

For all cases, it is essential to gather information on the complaint from the complainant. This can be done either by interview or by sending out a suitable Complaint Questionnaire. The use of a questionnaire sent to the complainant prior to any monitoring can greatly assist in determining the best time to witness the disturbance and likely length of assessment period. A sample complaint questionnaire is included at the end of the document as an Appendix. It may be decided that if the questionnaire is not returned within a suitable period, the complaint shall be considered closed.

[1] Shields, P *A Critical Review of Methodology used to Assess Ground Borne Railway Noise Complaints*. MSc Dissertation, Derby University. 2003

[2] Type of train and/or railway plus phenomena giving rise to complaint

4. On arriving at the property

If there is no information on the complaint or if clarification is required, the complainant can be asked to provide a subjective assessment of the complaint and its cause(s). It is also important for the test engineer to perform a walk-through test to gather information. Details of what to note in the walk through test are given later in the document.

5. Choice of Measurement Room

Room chosen by complainant or room deemed most suitable by engineer.
The key factors to consider are:

1. Habitable room
2. Train noise considered subjectively loud by complainant
3. Low background noise

In general terms, a ground floor living room is usually the best choice, however if this is not suitable, the alternative room chosen for measurements should always be a habitable room, not a storeroom, hallway, or bathroom. Kitchens are also not recommended as background noise from fridges, freezers etc can interfere with measurements.

Where possible the room that is quietest (least influence from both external and internal background noise sources) in the absence of train noise shall be chosen. It may not be obvious to the complainant or the test engineer as to which room produces the highest levels of train noise and it may be necessary to take a few sample measurements in a number of rooms to determine which one is the most suitable for the assessment. Ideally, more than one room should be assessed, however the decision shall be judged on the frequency of trains, the time available for measurement and/or the budget of the client.

Note also that the amount of soft furnishing in a room will also have an effect with the sound level in a sparsely furnished room being generally higher than a room with heavy carpets, drapes and soft furnishing. This should be taken into account for the choice of room and noted in the report.

6. Controllable sources of background noise and vibration

Due to the relatively low levels of railway ground borne noise generally encountered, measurements are often corrupted by either internal or external background noise. Whilst external background noise sources may be difficult to control, much can be done to mitigate the internal sources of background noise (and vibration). Mitigation can be achieved by asking the complainant to agree to the following:

- washing machines, dishwashers, heating systems, etc should be turned off during measurements;
- no DIY activities should take place, particularly drilling and hammering;
- avoid door slams, walking around house and moving furniture;
- ask the complainant to avoid using the bathroom if possible, and particularly to minimise flushing the toilet;
- clocks with load ticking mechanisms and/ or chimes should be switched off or moved to another room; and

- ensure that noise from any audio entertainment, TV, radio hifi does not interfere with measurements.

7. The ideal environment

The ideal situation is to have unnecessary persons vacate the house during measurements with all possible internal noise sources switched off, leaving the engineer to concentrate on capturing the event accurately. Ideally, the engineer should remain outside the measurement room to avoid creating unnecessary noise. If the engineer is to remain in the measurement room then squeaky chairs and creaking tables should be avoided! Mounting the microphone in the measurement room and running an extension cable to the measurement system in another room will usually provide the best situation. This offers two benefits:

- Noise caused by the engineer or measuring equipment is unlikely to influence the measurements.
- A dialogue can be maintained with the complainant, allowing him or her to verify whether the trains at the time of measurement are typical of those causing the disturbance in terms of loudness, speed, temporal and spectral content and duration.

Where possible the noise in the room should be monitored visually on instrument display and aurally using good quality headphones with decent low frequency response.

8. Measurement position within the chosen room

The influences of room acoustics can cause significant variations in level with measurement position. It is recommended that a position 1m off room centre and 1.2m above floor height be used as the standard measurement position.

9. Condition of the room

All windows, doors and ventilators should be fully closed to minimise extraneous noise sources. If it is impractical to close certain doors or windows, then the positions of these should be noted in the log and used for all future measurements.

10. When to measure

Measurements should be made at times during which:

- the trains that cause the disturbance are present;
- the background noise is low;
- the complainant feels the trains are more noticeable; and
- the train service is operating normally, i.e. running a full service at line speed.

If the problem is caused by trains at unsociable hours, e.g. engineering trains or heavy freight trains then arrangements must be made to measure at these times. (Unmanned monitoring may be suitable in these cases providing that background noise is low).

Due to the relatively low levels of ground borne noise it is important to measure at times during which the background noise is low, otherwise measurements will be corrupted. For the purpose of GBN measurements that background noise be defined as the L_{Aeq} value, measured in the absence of trains, over a minimum 10 minute sampling period. In certain circumstances, it will be necessary to include the

contribution of a number of shorter samples of background noise, depending on the interval between trains and the occurrence of random non-train events. The minimum length of each background sample should generally be not less than 30 seconds.

Some of these factors may, however, be overridden by the time(s) at which it is convenient for the engineer, equipment and/or complainant to be available

11. How long to measure for

The duration of the measurement exercise will depend on what is deemed to be representative. It should include a sufficient number of trains coving the inter-event variability measured successfully without corruption from background noise events. At least five and preferably ten or more trains of each type should be measured. A smaller sample may be considered in cases where trains are infrequent, provided that the complainant deems them to be representative of the ones causing annoyance. Note if there are several types of train, then for complaint purposes, it is usually unnecessary to measure a large sample of the quieter ones.

12. Sound Level Meter Settings

Whilst it is recognised that there is a range of more complex instrumentation in existence, these systems are not always readily available or necessary for an assessment. This guide is limited to the use of standard sound level meters (SLMs) that can be used to provide an on-site assessment of nuisance thus optimising the time spent dealing with the complaint. If further investigation is necessary it is recommend that the raw signal is recorded to allow a range of analysis techniques to be explored[3].

The meter shall be set to A-weighting, fast time constant and set to display the $L_{Amax,fast}$ value. The $L_{Amax,fast}$ value is should be noted for each train pass-by and reset after each train.

Sound SLM with a logging function (e.g. BK2238) can be set to log continually these parameters every second. If the data is to be used for research purpose and assuming that it is possible to measure other parameters simultaneously then $L_{Amax,slow}$, should also be measured.

13. Unmanned Monitoring

Unmanned monitoring may seem an ideal method to adopt in situations where the trains causing the disturbance occur infrequently or during unsociable hours. This technique is suitable only if a recording of the raw signal of the event is taken that can be replayed and/or analysed so as to establish whether or not the event has been corrupted by background noise events. Simple maximum level measurements are not suitable for unmanned monitoring as it is often impossible to distinguish between spurious events and train noise, or if two trains passed simultaneously.

3 It should be noted that the analysis should take into account the measurement uncertainty due to limitation of the recording and/or analysis systems especially in regard to fluctuating low frequency components. The instrumentation used should not be viewed as an infallible block box that will process accurately all the components of the real signal that existed in at the time of measurement. If in any doubt, the advice of the equipment supplier should be sought.

Exceptions to this can occur if the complainant is willing to keep a log of train times during the unmanned exercise. Ideally, the unmanned system should trigger on the vibration of the approaching train as there are usually fewer spurious background vibration events compared to sound pressure level and the latter will result in incidences of false triggering.

14. What to Note in the Log

14.1 Details of the property and the railway

- Measurement location within the building
- Form of building (e.g. terrace, detached, high-rise flat)
- Number floors
- Construction of building, e.g. brick, reinforced concrete
- Foundation type, e.g. strip, pile
- Name(s) of the railway
- Location of railway tunnel(s) relative to the building if known[4]
- Type of tunnel, if known
- Type(s) speeds and direction of trains[5]

14.2 Details of each train pass-by

Note the time of the event and any information on the character of noise. It may be possible to determine a number of specific "types" of train, the character of which may be attributable to train type, direction or a specific defect such as wheel flats.

14.3 Other / background noise sources

Note the details of acoustically significant effects that may influence the subsequent analysis of the data. For example, any periods during which noisy activities such as barking dogs, building work, etc., occurred should be noted, and if necessary, the data from these events discounted.

14.4 Details of the room

It is usually impractical to measure the reverberation time in a room; however, a note should be made of the amount of soft furnishings present. These should include details of floor coverings, presence of heavy drapes and amount of soft furnishings.

14.5 Other relevant factors to note in the log

- Include photos and a sketch of room showing the measurement positions within the room.
- Details of weather conditions during, and in general terms in the weeks prior[6] to measurements.

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[4] Sometimes it is possible to obtain details of the location of tunnels relative to then property, however this information may not be readily disclosed by the railway company not least for reasons of security

[5] Information on train will depend on the nature of the measurements, but such details may be useful in finding the cause of the complaint, especially if not all trains are considered a problem

[6] Extended periods of dry or wet weather can lead to changes in vibration transmitted to the property.

15. Using a Spotter to Identify Trains

In situations where there is a suitable vantage point to observe the approach of trains to the measurement position, having someone to spot trains can prove beneficial in a number of scenarios. In most situations, there is no line of sight to the trains the spotter can be used to help identify train direction and type.

If the spotter is in contact with the test engineer, he or she can inform him of the approach of trains and of their type, number of vehicles, loading, general condition and possibly speed. Note that mobile phones and other communication systems can interfere with sensitive measurement equipment and should be tested prior to use. If the communication system is found to interfere with the measurement apparatus it is important to establish a protocol whereby the communication system is not used during measurements of specific events, be they train pass bys or background noise.

The spotter should be positioned at the closest suitable vantage point to the measurement location. The spotter should note train speed and type and where possible the train identification number should also be recorded, as this will allow "rogue" trains to be identified. Note that synchronisation of all timing and measurement devices are essential to allow a comparison. If both spotter and test engineer note train pass-by times it is usually possible to determine individual events at the property.

16. Competence

Persons responsible for dealing with complaints about noise and vibration shall be proficient in dealing with members of the public. They shall be conversant with this document and aware of the various organisations available to assist with resolving a complaint.

Persons carrying out noise and vibration measurements, analysis and interpretation of the data and giving advice on the findings shall have received specialist training and experience in this field, with knowledge of railway acoustics. Equipment used for noise and vibration measurements and recordings shall be properly calibrated and conform to the relevant standards.

17. Analysis of Data

Data should be tabulated to show times and levels of individual trains. Any trains pass-by during which the measurement may have been corrupted by background noise or if two trains[7] passed simultaneously should be ignored.

18. Walk Through Test - Subjective Assessment

18.1 Background Noise

i. Levels of background noise;
ii. Sources of background noise generated inside the house; and
iii. Sources of background noise from outside.

[7] If two trains passing simultaneously is a regular occurrence then it can be included in the assessment, however the incidence is generally low and should be ignored, as it does not represent the norm.

18.2 Perception of train vibration

i. Can it be felt?
ii. Can effects of vibration be observed (e.g. objects swaying or heard to rattle)?
iii. Do effects vary from room to room?
iv. Are different types of events distinguishable?
v. Character of each event (e.g. continuous rumble, intermittent or regular thumps, corrugation noise, etc.).
vi. Duration of individual events (typical and variation)
vii. Frequency of events
viii. Signs of vibration damage

18.3 Perception of train noise

i. Does it vary from room to room?
ii. Are different types of events distinguishable?
iii. Character of each event (as above)
iv. Duration of individual events (typical and variation)
v. Frequency of events

19. Mitigation

The level of noise experienced in rooms depends on the radiation efficiency of the room and acoustic properties of the contents. There is little that can be done be the complainant to control this type of noise, however the following may have some benefit, but should be judged on a case by case basis:

- Increasing the amount of soft furnishing in a room.
- Reducing the amount of secondary radiation from household objects by vibration isolation or damping using a variety of simple methods.
- Installing floating floors and building a room within a room are other more drastic methods but great care should be used to ensure that natural frequencies of the isolation systems do not coincide with the dominant ground borne vibration frequencies.

Mitigation of ground borne noise and vibration from railways is best dealt with at source however, this subject is beyond the scope of this document. Information on potential mitigation methods can be found in the literature listed below. Great caution should be used when deciding on a suitable mitigation method, as what works well in one situation can prove ineffective or detrimental in another.

20. Further guidance can be obtained from the following references:

1. BS ISO 14837-1 (Draft) 2003. Mechanical Vibrations - Ground-borne vibrations arising from rail systems in tunnels - Part 1: Guidance on prediction models
2. Thornley-Taylor, R, et al. 2002 *Measurement and Assessment of Ground-borne Noise and Vibration - ANC Guidelines* Fresco, Great Britain
3. Noise Management Guide - Guidance on the Creation and Maintenance of Effective Noise Management Policies and Practice for Local Authorities and their Officers - Consultation Draft. Chartered Institute of Environmental Health. 2003.

21. Complaint Questionnaire

The questionnaire on the following pages may be used to gain useful information from the complainant.

APPENDIX - QUESTIONNAIRE FOR PEOPLE EXPERIENCING NOISE AND VIBRATION FROM TRAINS RUNNING UNDERGROUND

In order to obtain further details regarding the nature of your complaint, you are invited to complete this questionnaire. Please fill in as many sections as possible, as the information you provide will enable a comprehensive survey with regards to your complaint to be undertaken. Any additional information that you wish to provide which is not covered in this questionnaire is welcomed.

1. You and your home/property

1.1 How long have you lived in this building?

10 years or less	11-30 years	31-50 years	51years +

1.2 Are you the sole occupant? If no please give the number of residents.…….. ……

1.3 Are you the owner / tenant of the property? Please circle the appropriate one.

1.4 How old is your property?

10 years or less	11-30 years	31-50 years	51-100 years	101 years +

1.5 How would you describe the building where you reside? E.g. terrace, detached, semidetached,

high-rise? ……

1.6 How many floors are there? Please give number. ..……..

1.7 If flats, what floor do you live on? Please give number. …..……

1.8 Is there a basement? …….

1.9 Is the lowest floor of your property made from ① solid concrete or ② floorboards (if known)? ……

o Has there been any significant modification to the structure of the building, such as digging out of cellars or replacement of structural walls? If yes please give details of any works done and when these modifications were carried out.

..……

……..

……...

2. Noise & Vibration Complaint

2.1 Exposure

2.1.1 Please give a date when you first began to notice the noise and/or vibration?……..

- Please give details of the time & days of the week you are usually at the property.

……

- Of the noise and vibration, does one bother you more than the other? If so, please indicate which and explain why.

……

……..……

2.1.4 When is the noise and/or vibration most noticeable? Please indicate which day(s) and at what time of day the disturbance normally occurs.

	Morning	Afternoon	Evening	Night time	Other
Day(s)					
Time					

2.1.4 When you are indoors with the windows closed, does the noise and/or vibration:

Disturbance	y or n	Comments
Wake you up?		
Prevent you getting to sleep?		
Make it difficult to hear the TV or radio?		
Interfere with conversation?		

Disturb anything else? (Please give details)
……

2.2 Source of Noise and/or Vibration

2.2.1 Has the noise and/or vibration:

	y or n	Comments
Gradually Increased over a period of time?		
Suddenly Increased?		
Absent for a time but suddenly reappeared?		
Vary from day to day?		

Other? (Please give details)
……

2.2.2 Which Railway Line do you feel might be causing the noise and vibration?

Source	Line?	Comments
Trains that run on the surface?		
Trains that run underground?		

Other? (Please give details) ……

2.2.3 How would you describe the character of the train noise you hear?

Type of noise	y or n	Comments
Rumble		
Impulsive (e.g. thumps or bangs)		
Screech		

Other? (Please give details) ……

2.2.5 How would you describe the character of the train vibration that you feel?

Type of vibration	y or n	Comments
Rumble		
Impulsive (e.g. thumps or bangs)		
Other		

2.2.6 Does anything in the house rattle when a train goes by? If so please give details

……
…

2.2.6 Do you feel that there is any: ① variation between trains, or are they all ② at a constant level? .

If so please give details
……
…

……..

- Is the noise and/or vibration worse in some rooms than others? ……..If so, please give details.

……

- Is there any particular reason why you may be more or less sensitive to noise than others? If so please give details

……..

2.3 Do you know of anyone in the area who has complained about the noise / vibration? …….
If so would it be possible to supply their contact details to include them in this survey?

3. PERCEPTION

Please score the following statements in terms of how much you agree or disagree.

Strongly agree	**1**
Agree	**2**
No feeling ether way	**3**
Disagree	**4**
Strongly disagree	**5**
Don't know	**6**

Statement	Score
The trains during rush hour (peak) are noisier than at other times	
The noisiest trains are generally the fastest ones	
I am more bothered by the number of trains I can hear rather than very noisy individual ones	
Train noise is more annoying during quiet times	
Living close to a railway line is bound to cause some noise and the level of some trains is acceptable to me	
Trains that cause vibration that I can feel are worse than ones that only cause noise	
Slow trains that are audible for a long time are worse than fast trains that pass quickly	
I would be more bothered by one or two loud trains per hour than by quieter (but nevertheless audible) trains passing every few minutes	

What annoys you most about the character if the noise? Put rank the following factors in order of importance (1 being most important, 4 being least important). If there are any other factors that you feel aggravate the situation, please add them and include them in your ranking

Factor	Ranking
• Loudness	
• Duration that each train is audible for	
• Number of trains per hour	
• Type of noise (steady rumble, thumps etc)	
• Other factors	

Thank you for your time in filling in this questionnaire. Please sign it (if you wish), date it and return in the pre-paid envelope to the address on the pre-paid envelope.

Signed…….…….. Date……