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HUMAN RESPONSE TO VIBRATION IN RESIDENTIAL ENVIRONMENTS (NANR209)

TECHNICAL REPORT 2

MEASUREMENT OF RESPONSE

31ST MARCH 2011

Jenna Condie, Andy Steele, Nathan Whittle, Philip Brown, David Waddington

NANR209 Technical report 2: Measurement of response

Foreword

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Preface

This document is one component of the Defra project NANR209 ‘Human response to vibration in residential environments’ final report.

The NANR209 Final Report consists of the following documents:

- Executive summary
- Final project report
- Technical report 1: Measurement of vibration exposure
- Technical report 2: Measurement of response
- Technical report 3: Calculation of vibration exposure
- Technical report 4: Measurement and calculation of noise exposure
- Technical report 5: Analysis of the social survey findings
- Technical report 6: Determination of exposure-response relationships

The project was performed at the University of Salford between January 2008 and March 2011. During that time the following University of Salford researchers worked on the project. David Waddington, Andy Moorhouse, Mags Adams, Geoff Kerry, Rodolfo Venegas, Andy Elliott, Victoria Henshaw, Eulalia Peris, Phil Brown, Andy Steele, Jenna Condie, Gennaro Sica, James Woodcock, Deborah Atkin, Nathan Whittle, Zbigniew Koziel, George Perkins, Natalia Szczepanczyk, Sharron Henning, Ryan Woolrych, Heather Dawes, Amy Martin, Maria Beatrice Aquino-Petkos, Laura Jane Buckley, Catherine McGee, Andrew Counce, Valentin Le Bescond, Stephanie Jones, Dawn Smail, Andrew King, Lauren Hunt, Michael Gerard Smith, Tomos Evans.

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EXECUTIVE SUMMARY

Based on a review of the literature and the best practice guidance available, a social survey questionnaire was developed to measure residents' self-reported annoyance and to provide data suitable for establishing exposure-response relationships between levels of annoyance and levels of vibration. The development of the questionnaire was influenced by a number of previous studies such as: the social survey questionnaire developed for the NANR172 Pilot Study of this research (Defra, 2007); best practice guidelines for the development of socio-acoustic surveys issued by ICBEN and presented in the current International Standard (Fields et al., 2001; ISO/TS 15666:2003); the Nordtest Method (2001) for the development of socio-vibration surveys, and a peer review of the social survey questionnaire by international experts in the field. In order to avoid influencing responses and reasons for participation in the research, the survey was introduced as a survey of neighbourhood satisfaction. The questionnaire design, through the use of sections, enables new sections to be added to the questionnaire so that specific vibration sources can be investigated in more depth. In addressing the 'response' component in the 'exposure-response' relationship, the questionnaire was designed to yield interval-level measurement data suitable for analysis with vibration measurement data via two response scales: the five-point semantic and the eleven-point numerical scales. This decision was largely founded upon the ability of the two scales to meet the criteria established by ICBEN (Fields et al., 2001) for socio-acoustic survey design. Detailed procedures were documented, following the field trial of the questionnaire, in terms of the role of the interviewer, the recording of information and the transfer of the data to the relevant database for subsequent analysis and to inform the vibration team responsible for the 'exposure' component of this research project.

1. INTRODUCTION

1.1 OUTLINE OF THIS TECHNICAL REPORT

To explore the human response to vibration in residential environments, a social survey questionnaire was developed to gather the responses of residents living near sources of vibration outside of their control. Previous research, existing policy, a peer review process, and current and available best practice guidance influenced the approach taken to response measurement. This technical report outlines the development of the social survey questionnaire and the three sources of vibration investigated within this research – railways, construction activity, and internal sources of vibration.

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Within the three versions of social survey questionnaire (see Appendices: Appendix 1 – railway specific questionnaire, Appendix 2 – construction specific questionnaire, and Appendix 3 – internal sources specific questionnaire) the following definitions are used consistently throughout to describe the three vibration sources investigated:

- railway – defined as *‘the railway, including passenger trains, freight trains, track maintenance or any other activity from the railway’*
- construction activity – defined as *‘construction activity, including demolition, piling road works, drilling, surface activity such as bulldozers and loading trucks and any other construction activity’*
- internal sources – defined as *‘sources of vibration outside your home but from within the same building, from human activity such as footsteps, door slams or machinery such as air conditioning, washing machines, plumbing or any other activity.’*

For ease, rather than the comprehensive definitions above, this report uses the terms railways, construction activity, and internal sources throughout. Source-specific sections for the three vibration sources under investigation are discussed, however, it is important to note that the social survey questionnaire was designed to allow any source of vibration to be researched in more depth. Further sections can be added to the social survey questionnaire should other sources of vibration require investigation.

1.2 OVERVIEW OF PRECEDING WORK

Within an increasingly urbanised world, vibration from transportation infrastructure such as railways and roads, and man-made activities such as industrial and construction works has the potential to be present in properties and buildings within the residential environment. Changes to the ways in which we live, for example, in densely populated areas, in apartment blocks, and work/live units, means that people may also be exposed to vibration from internal sources such as domestic appliances (e.g. washing machines and air conditioning units), and from the activities of neighbours in adjacent or nearby properties (Howarth & Griffin, 2008).

Our residential environments are central to ensuring quality of life, health, and well being. It is therefore important to evaluate, understand, control, and regulate the environmental conditions that we live with such as vibration, noise, and air quality. Vibration is largely considered as something which is unwanted and undesirable due to the range of associated negative impacts upon people, most notably annoyance (e.g. Defra, 2007; Herranz-Pascual et al., 2009; Klæboe et al., 2003) and sleep disturbance (e.g. Arnberg et al., 1990; Ögren et al., 2008; Öhrström et al., 2009). Although vibration is not annoying or disturbing for everyone, it is rarely considered as a desirable or positive feature in a residential context.

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How we experience vibration is complex. Our ability to sense vibration depends on its frequency, duration, and direction (Griffin, 1996) and its detection is reliant upon a range of signals from the visual, vestibular, somatic, and auditory systems of the body (Mansfield, 2005). We can feel vibration through the haptic (sense of touch) and kinaesthetic (sense of movement) sensory systems, but we can also hear and see the effects of vibration through the auditory and visual sensory systems. Due to the range of sensory systems involved, our perception of vibration is an intricate and obscure process which has implications for investigating the responses of residents to vibration in the residential environment.

The English language has many words to describe what we can see, fewer for what we hear, and even fewer for what we can feel in comparison (Landry, 2006). Subsequently, our response to vibration in the residential environment may be difficult to describe, and highly variable considering its multi-sensory nature. When people are asked about vibration they often describe the associated noise and visual sensations alongside the physical sensation of feeling vibration (Defra, 2007). Vibration is often accompanied by noise and '*vibration effects may be more subtle and less noticeable than noise*' (Defra, 2007, p.22). Residents may also be uncertain of the differences between noise and vibration (Howarth & Griffin, 2008). With the linguistic shortcomings, coupled with a multi-sensory experience and accompanying visual (e.g. seeing the vibration source, seeing objects move) and auditory (e.g. hearing sound from the vibration source) information, it is important that residents' responses to vibration are enquired about in a clear and comprehensible way. It is also imperative that any associated noise is also considered within research on vibration in the residential environment.

The responses of residents to vibration and noise are often measured in terms of annoyance. Annoyance has been defined as a psychological phenomenon (Stallen, 1999) and is largely considered as the negative evaluation of environmental conditions by residents; closely associated with terms such as disturbance, nuisance, discomfort, and dissatisfaction (Guski, Felscher-suhr, & Schumer, 1999). In relation to noise, Miedema (2007) argues that annoyance '*is a sensitive indicator of adverse noise effects and by itself means that noise affects people's quality of life*' (p. 43). Thus, measures of noise annoyance are often taken as an indication as to the quality of a person's acoustical climate. Transferring the annoyance approach to vibration, similar understandings of vibration as having implications for quality of life are also made.

Within annoyance research, residents are generally asked about how bothered, annoyed, or disturbed they are by environmental conditions such as vibration, noise, and air quality. The level of reported annoyance is often correlated with any measurements that can be taken of the environmental condition to establish an exposure-response relationship. Studies aiming to establish exposure-response relationships for noise annoyance and the acoustical characteristics of noise have been carried out since the 1970s (e.g. Cawthorn, et al., 1978; Fields & Walker, 1982; Miedema & Vos, 1998; Schultz, 1978). For noise, Miedema (2007) highlights the extensive body of research which has provided exposure-response relationships with the ultimate aim of predicting the level of annoyance for any given noise level. More

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recently, efforts to establish an exposure-response relationship for vibration in residential environments have also been carried out (e.g. Defra, 2007; Herranz-Pascual et al., 2009; Klæboe et al., 2003).

Residents' annoyance responses have largely been collected by quantitative social survey questionnaires. Questions about annoyance and scales measuring the levels of annoyance reported are often included to provide suitable data for comparison and analysis with measurements of exposure. This research developed a social survey questionnaire to gather annoyance responses from residents' living near railways, construction activity, and with internal sources of vibration.

2 DETERMINATION OF RESPONSE

2.1 INTRODUCTION TO DETERMINATION OF RESPONSE

By drawing upon the literature reviewed above, and the best practice guidance available, a social survey questionnaire was developed to measure residents' self-reported annoyance and to provide data suitable for establishing exposure-response relationships between levels of annoyance and levels of vibration. Residents' self-reported annoyance for noise was also covered in this social survey questionnaire, due to vibration and noise often being experienced together. Annoyance was taken as the main measurement of response due to its applicability for developing policy guidance and international standards. However, the way we respond to vibration in the residential environment is much more complex. The annoyance approach is one of many ways in which the response to vibration in the residential environment may be understood. As such, the social survey questionnaire aimed to collect data on a number of other factors that may be influential, for example, vibration and noise sensitivity, self-reported ratings of acceptability, and satisfaction with the neighbourhood and home.

2.2 DEVELOPMENT OF THE QUESTIONNAIRE

The social survey questionnaire aimed to gather the responses of people to vibration and noise in residential environments. This section discusses the content and structure of the questionnaire in depth and the rationale behind the inclusion, exclusion, and development of each question.

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The basis for the development of the social survey questionnaire was:

- 1) the social survey questionnaire developed for the NANR172 Pilot Study of this research (Defra, 2007);
- 2) best practice guidelines for the development of socio-acoustic surveys issued by ICBEN and presented in the current International Standard (Fields et al., 2001; ISO/TS 15666:2003);
- 3) the Nordtest Method (2001) for the development of socio-vibration surveys;
- 4) a social science peer review carried out within this research;
- 5) a peer review process where international experts in the field were asked to review the questionnaire; and
- 6) preliminary field trials carried out within this research.

2.3 THE SOCIAL SURVEY QUESTIONNAIRE

The development of the social survey questionnaire has been heavily influenced by the work of the International Commission on Biological Effects of Noise (ICBEN). Their criteria for socio-acoustic survey design have been included and adapted for the development of this social survey questionnaire to investigate vibration.

The social survey questionnaire should:

- Be clear and comprehensible for the respondent to provide a valid rating of annoyance;
- Allow exploration of any combined effect of vibration and noise on annoyance;
- Yield an interval-level measurement scale (i.e. the response scale answers are equally spaced meeting the assumptions for analysis techniques);
- Yield data suitable for analysing exposure-response relationships with objective vibration and noise measurements; and
- Permit consistency throughout the questionnaire for ease of administration and comprehension for interviewers, respondents, policy makers, and report readers.

(adapted from Fields et al., 2001)

These criteria structured and directed the development and design of the social survey questionnaire, from its content (e.g. questions asked, response scales used), to its format (e.g. questionnaire scripting and routing), and approach (e.g. annoyance as response measurement). The main aspects of the questionnaire design are now discussed below. Three versions of social survey questionnaire are included in the appendices (Appendix 1 – railway specific questionnaire, Appendix 2 – construction specific questionnaire, and Appendix 3 – internal sources specific questionnaire).

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2.4 INTRODUCING THE SURVEY

In order to avoid influencing responses and reasons for participation in the research, the survey was introduced as a survey of neighbourhood satisfaction. The introductory sections of the questionnaire focus on respondents' reasons for moving into the neighbourhood and neighbourhood satisfaction, before moving onto specific questions on vibration and noise. If respondents were aware that the purpose of the survey was to investigate response to vibration and noise in residential environments, the answers and ratings may have depicted higher annoyance levels (see for example Nordtest Method, 2001).

However, evaluations of environmental conditions such as noise (e.g. Fields & Walker, 1982; Parkes et al., 2002), air quality (Day, 2007) and crowding (e.g. Bonnes et al., 1991) have been found to be related to satisfaction with the neighbourhood. Thus, neighbourhood satisfaction is a relevant and potentially important aspect to consider in this context, whilst also providing a suitable pretext for the research.

The Pilot Study (Defra, 2007) used the guise of a questionnaire exploring the effects of local traffic. In contrast with a neighbourhood satisfaction survey, a local traffic survey would be more likely to place the survey in the realm of vibration and noise and could subsequently have influence on a study's findings. It would also become clear, as the questionnaire progresses that it is not about the effects of local traffic. Such circumstances could risk the development of rapport and trust between the interviewer and respondent; and later agreements to vibration measurements being taken within residents' properties.

Introducing the survey as one of neighbourhood satisfaction goes some way to address some of the issues above. However, this approach may also result in some respondents not taking part in the survey who would otherwise participate if the survey was introduced as a survey of vibration in residential environments.

2.5 QUESTIONNAIRE STRUCTURE

The aim was to develop one questionnaire that could be used to investigate any source of vibration in the residential environment, yet each source of vibration is different, for example, some vibration sources are permanent (e.g. railway), and some are temporary (e.g. construction). The questionnaire design enables new sections to be added to the questionnaire so that specific vibration sources can be investigated in more depth. When such source-specific sections are added they should be standardised as much as possible so that comparisons can be made between data for different sources of vibration. However, is not always possible or appropriate to standardise new sections for other vibration sources, as each source of vibration has different characteristics and associated issues. For example, some sources of vibration can be permanent (e.g. railways) whereas others can be temporary (e.g. construction activity) within the residential environment. Furthermore comparisons

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between datasets for different sources of vibration may be difficult and not always possible. For example, different time periods (e.g. in the last 12 months or so, in the time you have been living here) may be needed for different sources of vibration. As such, any comparisons between the responses for different sources of vibration should take into account any differences between the social survey questionnaires.

The vibration sources explored within this research were railway activity, construction activity, and internal sources. Each vibration source investigated resulted in two further sections being added to the questionnaire – one to explore response to vibration from the source, and one to explore responses to noise from the source in more depth. As such, six source-specific sections were included in this social survey questionnaire, two for each of the three sources of vibration considered (the social survey questionnaires with source-specific sections are available in Appendix 1, 2, and 3).

The sections of the social survey questionnaire in order are as follows:

Section A: Dwelling information – this section contains questions regarding the dwelling and surrounding area and was to be completed by the interviewer without the respondent. Following on from the Pilot Study (Defra, 2007) this section was included to gather some information about the property type (e.g. semi-detached), the number of storeys or floors (apartment blocks) in the property, and the type of residential area (e.g. residential/industrial/commercial/countryside) the property is situated within.

Section B: Neighbourhood satisfaction – this section contains questions about the neighbourhood, such as reasons for living in the neighbourhood, how long the respondent had lived in the area, and whether the respondent liked or disliked the neighbourhood. Measures of neighbourhood satisfaction are also included.

Section C: Satisfaction with home – this section contains questions about the property such as why the respondent moved to their home, how satisfied they were with their home, and whether the respondent wanted to move home in the future. Tenure type and aspects that could not be completed without the respondent in Section A are also gathered e.g. type of windows, whether property has a cellar/basement, what infrastructure can be seen from the property.

Section D: Vibration questions – this section contains general questions about feeling, hearing, and seeing vibration in residences. The answers given in this section acted as a filter and determined whether the source-specific section on vibration was completed. Questions on annoyance, acceptability, sensitivity, and future expectations of vibration are also gathered in this section. Vibration questions preceded questions on noise as vibration was the main focus of this research.

Section E: Noise questions – this section contains general questions about noise the respondent may hear whilst inside their home. The answers given in this section also acted as a filter and determined whether the source-specific noise section is completed. Questions on annoyance, acceptability, sensitivity, and future expectations of noise are also gathered in this section.

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Section F: Railway vibration – this section was only completed if the respondent, in Section D, stated that they were bothered, annoyed or disturbed by vibration from the nearby railway. Specific questions were asked about what particular railway activities caused disturbance, and how annoying was the vibration during the day, evening, and night.

Section G: Railway noise – this section was only completed if the respondent, in Section E, stated that they were bothered, annoyed or disturbed by noise from the railway. This section mirrored Section F (Railway vibration) in order to allow the data to be compared and combined in analysis.

Section H: Construction vibration - this section was only completed if the respondent, in Section D, stated that they were bothered, annoyed or disturbed by vibration from the nearby construction activity. Specific questions were asked about what particular construction activities caused disturbance, and how annoying was the vibration during the day, evening, and night.

Section I: Construction noise - this section was only completed if the respondent, in Section E, stated that they were bothered, annoyed, or disturbed by noise from the construction activities. This section mirrored Section H (construction vibration) in order to allow the data to be compared and combined in analysis.

Section J: Internal sources vibration - this section was only completed if the respondent, in Section D, stated that they were bothered, annoyed or disturbed by vibration from internal sources of vibration. Specific questions were asked about what particular internal sources cause disturbance and how annoying was the vibration during the day, evening, and night.

Section K: Internal sources noise - this section was only completed if the respondent, in Section E, stated that they were bothered, annoyed or disturbed by noise from internal sources of vibration. This section mirrors Section J (internal sources vibration) in order to allow the data to be compared and combined in analysis.

Section Y: Personal and occupancy information – this section contains questions enquiring about general demographic information (age, gender, ethnicity, employment status, occupation) and also the times of day during the week and at weekends that the respondent was at home.

Section Z: Interviewer assessment of vibration and noise – this section contains questions for the interviewer to answer about their experience of vibration and noise in the respondent's home. This section was completed, at a suitable time, once the interviewer has left the property.

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2.6 QUESTIONNAIRE ROUTING

Due to the complexity of this questionnaire's focus (i.e. vibration) and the need for detailed information about the respondents' experiences of vibration and noise in their homes, filter questions were felt to be a necessary addition to the social survey questionnaire's design. The Nordtest Method (2001) defined filter questions as those '*posed before the actual annoyance question. Filter questions are used to select only the people who are affected by the environmental effect one wishes to measure people's reaction to*' (p.3). Filter questions have been found to bias responses (Grimwood et al, 2002), and should therefore be used minimally throughout a questionnaire. Hence, it should be noted that filter questions are optional, and that socio-vibration and socio-acoustic surveys can be designed without them using questions with an option such as '*do not notice*' for different sources of vibration and noise.

In Section's D and E of the social survey questionnaire, respondents are first asked about which sources they feel (D1), hear and/or see (D5) vibration, and hear noise (E1) from in their homes. These questions allow the interviewer to filter out respondents' who do not experience vibration and noise from any of the sources within their homes, as subsequent questions would not be applicable for them. More importantly, these questions also enable the interviewer to ask respondents further questions about the sources of vibration and noise they do experience. As such, respondents' are asked only questions that are relevant to the vibration and noise they experience within their homes. Filtering also ensured that the social survey questionnaire would take around twenty minutes to complete with each respondent. A survey that would take longer than twenty minutes, given the recruitment method of door-to-door knocking, could have impacted upon participant recruitment success rates.

2.7 DEFINITIONAL AND SEMANTIC ISSUES

This section addresses the definitional and semantic issues when designing a social survey questionnaire to gather residents' responses to vibration in the residential environment. It is crucial that the terminology used in the questionnaire is clear and comprehensible to ensure respondents fully understand the questions being asked. Although, it should be noted that all respondents will inevitably make their own individual interpretations of the questions due to the subjective nature of measuring response. As such, a preliminary field trial of the social survey questionnaire was carried out to ensure the appropriateness of the terminology used in the main studies of this research.

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2.7.1 DEFINING THE NEIGHBOURHOOD

There is currently a shift in policy discourse towards the term ‘neighbourhood’, away from previously used terms such as ‘community’ and ‘area’ (Meegan & Mitchell, 2001). In addition, the use of the term ‘area’ may be less likely to illicit responses considering community aspects, whilst implying a larger geography, and may also lead respondents to focus more on the physical aspects of their residential environment. The term ‘neighbourhood’ has been applied throughout the questionnaire to illicit more accurate responses of satisfaction, and account for more abstract concepts, such as ‘community cohesion’. The term has been left undefined in the questionnaire, to allow respondents to self-define the neighbourhood when answering the survey questions. If the interviewer was to qualify what is meant by ‘neighbourhood’, the definition used may not have corresponded with what the respondents themselves regard as their neighbourhood and therefore the data collected would be invalid. It could also lead respondents to disregard environmental annoyances on the basis that they are not in the given definition and, as a result, important data could have been lost.

2.7.2 DEFINING THE RAILWAY

Drawing on the terminology employed by the Pilot Study (2007), and the preliminary field trial of this research (see section 3.1 - Field Trial Study); the definition of what is meant by ‘railway’ was reviewed, particularly in light of comments made by field trial respondents. Following the pilot study which defined railway as ‘overground trains’, the preliminary field trial questionnaire used this terminology. When the term ‘overground trains’ was used, it was understood by respondents that this meant passenger trains and freight trains. This was evident when asking questions about whether there was one type of train that caused the most annoyance, with people specifically identifying freight trains and passenger airport link trains for example. However, in discussions with respondents, other vibration sources from the railway were identified that potentially would not have been recorded if ‘overground trains’ was used e.g. track maintenance. This could result in respondents not being routed to the source-specific sections when they were bothered, annoyed, or disturbed by vibration from the railway that was not caused by train activity.

Full definitions of what was meant by ‘railway’ were placed within all of the questions regarding or referring to railway. In the ‘satisfaction with the home’ section, the interviewer read “*From any room in your home, can you see a railway track or any type of passing train?*” In the general vibration section, the interviewer read “*In the last 12 months, have you felt any vibration or shaking anywhere in your home that you think was caused by the railway, including passenger trains, freight trains, track maintenance or any other activity from the railway?*” This definition was also repeated when respondents’ ratings of annoyance

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were gathered in the general noise and source-specific sections of the questionnaire. The definition of railway within the general vibration and noise sections allowed for successful routing to the source-specific sections, in which the particular sources of annoyance (e.g. passenger trains, freight trains, track maintenance) were identified in more depth.

2.7.3 DEFINING CONSTRUCTION ACTIVITY

From the preliminary field trial for railway (see Section 3.1: Field trial study), the same approach was adopted for construction activity, keeping the definition broad to encompass all types of vibration that the resident might experience. Throughout the questionnaire, the construction activity was defined as '*construction activity, including demolition, piling, road works, drilling, surface activity such as bulldozers and loading trucks and any other construction activity*' in order to ensure that all construction activities were taken into consideration by the residents when they were asked whether they feel, and whether they hear/see vibration from construction activity. This lengthy definition ensured that respondents were routed through appropriately and consistently to the annoyance questions in both the general and source-specific vibration and noise sections.

Within the source-specific sections on vibration and noise from construction, the following activities were enquired about independently - demolition, piling, road works, drilling, surface activity such as bulldozers and loading trucks, and other construction activity (with a further option to specify what the 'other' activity was).

2.7.4 DEFINING INTERNAL SOURCES

For internal sources, the approach taken when defining the railway was adopted, again to ensure that all potential internal sources of vibration would be accounted for by its definition. Throughout the questionnaire internal sources were defined as '*sources of vibration outside your home but from within the same building, from human activity such as footsteps, door slams or machinery such as air conditioning, washing machines, plumbing or any other activity*', to ensure that respondents who felt vibration from an internal source were successfully routed to the annoyance questions. Internal sources of vibration were also inquired about within the same time frame as railway '*in the last 12 months or so*' as it is difficult to predetermine whether internal vibration sources are of a temporary or permanent nature. In the source-specific internal vibration sections for vibration and noise, additional sources were inquired about independently. It was important for this source that an '*other*' option with '*please specify*' were included due to the potentially vast number of internal vibration sources that could be experienced within the home.

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2.7.5 DEFINITIONAL ISSUES AND COMPARISONS ACROSS THE DATA

This approach taken within this research was to develop a questionnaire which could be tailored to attend to the different issues associated with particular sources of vibration; to be implemented at sites specifically identified for vibration from the source under investigation. As such, each social survey questionnaire developed included more detailed definitions of the investigated source (see Sections 2.7.2 – Defining the railway, 2.7.3 – Defining construction activity, and 2.7.4 – Defining internal sources) to ensure that respondents noticing vibration and noise from the source were successfully identified and routed to further questions.

By adopting this approach, caution should be taken when making comparisons across the data collected by the different social survey questionnaires, as more concise definitions for each of the three sources are used where they appear in other questionnaires that focus on one of the other sources. For example, within the social survey questionnaires' designed specifically for railways and construction activity, respondents were asked about vibration and noise from '*footsteps, slamming doors, domestic appliances in neighbouring homes*'. As the internal sources specific questionnaire employed a more in depth definition of internal sources (see section 2.7.4 – Defining internal sources), any comparisons between datasets should take account of this definitional issue.

2.8 ASKING ABOUT VIBRATION

It was important to ask residents about the vibration they experience in a clear and consistent manner. In order to support respondent comprehension, when asking about the vibration respondents felt in their homes, the word '*shaking*' was also included. Similarly, when asking about the vibration respondents heard or saw in their homes, the words '*rattle, vibrate or shake*' were used. Furthermore, the questionnaire included questions which asked respondents to consider how they noticed the vibration i.e. through which structures (e.g. floor, chair, and bed) and which structures/objects they heard or saw rattle, vibrate, or shake (e.g. doors, windows, and crockery).

In line with the Pilot Study (Defra, 2007) the questionnaire considers 'feeling' vibration separately from 'hearing' and 'seeing' the effects of vibration in residential environments. Building vibration may be transmitted to the body and subsequently felt by the person through the floor, chair, bed or other surfaces (Howarth & Griffin, 2008). Thus respondents are asked the following:

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D2. When you have felt vibration, have you felt it:		
	Yes	No
From the floor	<input type="checkbox"/>	<input type="checkbox"/>
When you have been sitting on a chair	<input type="checkbox"/>	<input type="checkbox"/>
When you have been lying on a bed	<input type="checkbox"/>	<input type="checkbox"/>
When you have touched any surfaces with your hands	<input type="checkbox"/>	<input type="checkbox"/>
From any other surfaces in this home	<input type="checkbox"/>	<input type="checkbox"/>

The other ways of perceiving vibration i.e. ‘hearing’ or ‘seeing’ its effects, are enquired about by asking the following:

D6. Have you personally ever heard or seen any rattling, vibrating or shaking of:		
	Yes	No
The windows	<input type="checkbox"/>	<input type="checkbox"/>
The doors	<input type="checkbox"/>	<input type="checkbox"/>
Any other part of this home	<input type="checkbox"/>	<input type="checkbox"/>
Crockery, like plates or glasses in your cupboards	<input type="checkbox"/>	<input type="checkbox"/>
Any other objects in this home	<input type="checkbox"/>	<input type="checkbox"/>

However, when asking about how bothered, annoyed or disturbed the respondent is by vibration, they are asked about ‘feeling’ and ‘hearing or seeing’ the effects of vibration simultaneously in one question aiming to uncover respondent’s levels of overall annoyance of the vibration they experience in their home.

2.9 THE ANNOYANCE RESPONSE SCALES

The social survey questionnaire addressed the ‘response’ component in the ‘exposure-response’ relationship. Response was characterised by respondents’ reported level of annoyance, the assessment of which was made possible by the inclusion of response scales

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which yield interval-level measurement data suitable for analysis with vibration measurement data. The questionnaire designed for this study used two response scales to measure an individual's level of annoyance. This section outlines the reasons for the response scales decided upon for this research.

As this is a growing area of research, it is accepted that there is no consensus on the type of scales that should be used to measure the relationship between vibration and annoyance in the residential environment. There are many response scales that could be used to gather respondents' reported levels of vibration and noise annoyance successfully. Subsequently, it is acknowledged that it is important to draw upon research conducted in other related areas, specifically the large body of knowledge on environmental noise research. The consideration of noise annoyance scales is also imperative as the questionnaire explores noise to further understandings of the human response to vibration in residential environments. Furthermore, as this research aimed to explore the relationship between vibration and noise annoyance, using response scales consistently throughout the questionnaire has important implications for data analysis.

The scales (and their associated questions) developed to measure response to vibration were done so in order to meet the following six characteristics, based on those of Fields et al., (2001) for noise:

1. Provide a high quality, reliable measure of a general reaction to vibration annoyance in a residential environment;
2. Yield an interval-level measurement scale able to meet the assumptions for regression and many other analysis techniques;
3. Be suitable for face-to-face questionnaire administration
4. Permit valid international comparisons of survey results within and between languages;
5. Yield transparent results that will be consistently interpreted by survey respondents, policy makers and report readers; and
6. Take the approach that is most likely to be adopted internationally.

The scales that were reviewed and evaluated in the development of the social survey questionnaire were the following:

- Four-point semantic scale, as used in Aircraft Noise Index Survey (ANIS), (Brooker, et al., 1985);
- Five-point semantic scale, as recommended by Fields et al., (2001) and ISO/15666: 2003 for socio-acoustic survey design;
- Seven-point semantic differential scale, as used in soundscapes research (see Defra, 2009);
- Seven-point numerical scale, as used in the Pilot Study (Defra, 2007) and the UK National Noise Attitudes Survey 1999/2000 (NAS) (Grimwood, et al., 2002) and

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- Eleven-point numerical scale, as recommended by Fields et al., (2001), ISO/15666: 2003 for socio-acoustic survey design and the Nordtest Method (2001) for socio-vibration survey design.

The semantic (or verbal) scales are discussed below, followed by a discussion of the numerical scales, and the scales that were chosen for inclusion in the social survey questionnaire.

2.9.1 SEMANTIC RESPONSE SCALES

Both four-point and five-point semantic response scales have been used to measure levels of annoyance, most notably within noise annoyance research but also within the growing body of research on vibration. Both these scales tend to be designed in unipolar format, running from a neutral (e.g. not at all annoyed) to a negative (e.g. extremely annoyed) position, as opposed to a bipolar scale which would run from a negative (e.g. very dissatisfied) to a positive (e.g. very satisfied) position. Examples of a four-point and a five-point semantic scale are depicted below:

The four-point semantic scale

Not at all	A little	Moderately	Very much
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(from ANIS, Brooker et al., 1985)

The five-point semantic scale

Not at all	Slightly	Moderately	Very	Extremely
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(as recommended by ISO/TS 15666: 2003)

The four-point semantic scale was used in the Aircraft Noise Index Study (ANIS) (Brooker et al., 1985). Brooker (2008) argued that the use of a four-point semantic scale prevents respondents taking the potentially easy option of selecting the middle value, thus avoiding a heaping effect at the middle point. This may be the case for bipolar scales where the middle point would be a neutral response, but the same cannot be said of unipolar scales (Fields et al, 2001). Fields et al (2001) analysed the responses of over 12,000 respondents, answering a total of 73 questions about 53 different noise situations. Fields et al (2001) concluded that the use of five points in a unipolar scale does not result in a heaping effect around the middle point as the middle point does not represent a neutral response.

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The five-point semantic scale appears the most dominantly used of the semantic scales (e.g. Herranz-Pascual et al., 2009; Klæboe et al., 2003; Lee & Jeon, 2008) at present which is likely due to its recommendation in ISO/15666: 2003 for socio-acoustic survey design, based on the work carried out by ICBEN (Fields et al., 2001). After reviewing over 300 surveys exploring noise, the five labels – not at all, slightly, moderately, very, extremely – were identified as being equidistant from one another (Fields et al., 2001).

A slightly different five-point semantic unipolar scale (see below) has also been recommended by the Nordtest Method (2001) for socio-vibration survey design, and applied in one of the few significant international studies of the response to vibration in residential environments (Klæboe et al., 2003).

The Nordtest five-point semantic scale

Highly annoying	Moderately annoying	A little annoying	Not annoying	Does not notice
----------------------------	--------------------------------	------------------------------	-------------------------	----------------------------

(as recommended by the Nordtest Method, 2001)

In practice, this five point semantic scale is a four point scale as only four of the points relate to ratings of annoyance. ‘Does not notice’ is not another point on the scale as it represents a different category of respondents all together, differentiating between those who do notice vibration, and those who do not. It would seem appropriate, given the focus of this research being on vibration, to adopt the same scales as recommended by the Nordtest Method (2001) guidance for socio-vibration surveys. However, as noise is closely related and influential in the response to vibration (Defra, 2007) the same scale should be used to explore both vibration and noise annoyance within the same social survey questionnaire. It is also important that the scales used are ones which allow international comparison with research on vibration and noise being conducted elsewhere. As noise annoyance research is widely adopting the five-point scale recommended by ISO/TS 15666: 2003, it was deemed appropriate and logical to adopt the same scale for vibration annoyance.

The 1999/2000 National Survey of Attitudes to Environmental Noise (Grimwood et al., 2002), conducted prior to the publication of the ISO standard, also adopted a five-point semantic scale for assessing annoyance in response to environmental noise. This is essentially the same scale from the ISO/TS 15666:2003 with the exception that the former used the term ‘a little’ in place of ‘slightly’. This scale was also adopted in the Pilot Study (Defra, 2007).

Another response scale that is often used within soundscapes research is the semantic differential scale (see Defra, 2009 for a review of soundscapes research methodology). The soundscapes approach is more holistic in that it is concerned with both the positive and the negative sounds in the environment. As such, semantic differential scales are commonly used, where respondents evaluate something on a scale of two opposing adjectives (e.g. good/bad, pleasant/unpleasant, tranquil/stressful) across a numerical range from 1 to 7 (Osgood, 1975). Individuals rate sound/soundscapes on a number of attributes or to compare

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pairs of acoustic stimuli (Defra, 2009). Such scales could be used to explore responses to vibration within the residential environment. However, as this research takes an annoyance approach to establish exposure-response relationships, annoyance is measured on a unipolar basis, rather than a bipolar basis as is more common within soundscapes research.

2.9.2 NUMERICAL SCALES

In developing the international standards for measurement of annoyance to exposure to environmental noise, the use of an eleven-point scale (0 – 10) was advocated due to the likelihood of it being easily understood by people from all countries and cultures familiar with decimal currency systems and other counting situations (Fields et al., 2001). An eleven-point scale is preferable to a ten-point scale because the perceived mid-point on both scales is 5, but this is not the case for ten-point scales where the mid-point is 5.5.

The eleven-point numerical scale

0	1	2	3	4	5	6	7	8	9	10
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(as recommended by ISO/TS 15666: 2003 and the Nordtest Method, 2001)

The eleven-point numerical scale has been recommended in ISO/TS 15666: 2003 for socio-acoustic survey design, and in the Nordtest Method (2001) recommendations for socio-vibration design. Subsequently, this particular scale was suitable for this research as residents' annoyance responses for both vibration and noise annoyance were required.

Other numerical scales, most notably seven-point unipolar numerical scales have been used in the past to measure annoyance levels in relation to exposure to noise and vibration, for example, in the Pilot Study (Defra, 2007) and the 1999/2000 National Survey of Attitudes to Environmental Noise (Grimwood et al., 2002). Levine (1981) promoted a seven point numerical scale with each point being assigned a specific modifier (semantic label), in an early attempt to standardise the assessment of annoyance to noise exposure. The Pilot Study (Defra, 2007) for this project explained the inclusion of a seven point numerical scale on the basis of it enabling comparison with other research studies such as Watts (1984) and Woodruff and Griffin (1987). However, while comparisons with prior research are important, the introduction of ISO/TS 15666: 2003 will likely mean that future studies will adopt the five-point semantic, and the eleven-point numerical scales.

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2.9.3 SELECTION OF ANNOYANCE RESPONSE SCALES

For socio-acoustic surveys, the diversity of options for response scales has previously presented a challenge to researchers, making comparisons across research difficult. As a solution, the work of ICBEN (Fields et al., 2001) laid the foundations for an international standard to be developed. Such developments can be seen as a positive step forward in the understanding of noise and annoyance. The ISO/TS 15666:2003 guidance states that surveys should employ two response scales in order to effectively assess annoyance levels, the five-point unipolar semantic scale and the eleven-point numerical scale. An advantage of using these scales is that, in addition to vibration annoyance, the survey explores noise annoyance. Implementing scales consistently throughout the questionnaire reduces respondent and interviewer confusion. Also using the same annoyance scales within both the noise and vibration sections will allow the exploration of combined effects; one of the central aims for this social survey questionnaire. Furthermore, in the absence of international standards for socio-vibration studies at present, the work within the field of socio-acoustics provides a suitable framework for the development and justification of the social survey questionnaire developed here.

After reviewing the arguments for all the scales discussed above, the conclusion was reached that the socio-vibration survey adopt the five-point semantic and the eleven-point numerical scales. This decision was largely founded upon the ability of the two scales in terms of meeting the criteria established by ICBEN (Fields et al., 2001) for socio-acoustic survey design and adapted here for the development of a socio-vibration survey (see Table 1 below).

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Table 1: Summary of the main semantic and numerical scales reviewed in the development of the social survey questionnaire

Response Scale Criteria	4-point semantic	5-point semantic	7-point semantic differential	7-point numerical	11-point numerical
1. Clear and comprehensible	✓	✓	✓	✓	✓
2. Combined effect of vibration and noise	✓	✓	✗	✓	✓
3. Interval-level measurement scale	✓	✓	✓	✓	✓
4. Exposure-response Relationship	✓	✓	✗	✓	✓
5. Consistency throughout the questionnaire	✓	✓	✓	✓	✓
6. Current best practice	✗	✓	✗	✗	✓
7. International comparisons	✓	✓	✗	✓	✓

Based on a review of the scales used in previous research and best practice guidance, this research employed the combination of these two scales to establish an exposure-response relationship for both vibration and noise.

Using response scales that are more likely to enable comparison with a number of other studies is important. However, researchers should recognise that any comparisons of the data collected with this social survey questionnaire should take into account the specific context within which this social survey was developed. For example, as this social survey questionnaire was designed with vibration as the focal concern, comparisons of the noise data should take into account that the presence of vibration in the residential environment, and that respondents are asked questions about vibration before they are asked about noise, could influence the noise annoyance responses collected.

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2.10 THE INCLUSION OF OPEN QUESTIONS

Throughout the questionnaire there are a number of questions that are open-ended and have been designed to collect qualitative data. Originally it was intended that this qualitative data would be collected at each interview and coded into categorical data at the data entry stage, effectively quantifying the qualitative data. While the research team could predict some of the responses for each of these open questions, based in part on the findings of the preliminary field trial (see section 3.1), the questions remained open-ended in order to allow for responses that had not been considered or could not have been foreseen. This avoided large numbers of ‘other’ responses and captured more meaningful data.

The value of qualitative data has long been recognised within the social sciences, being seen as a prerequisite for good quality quantitative research (Pope & Mays, 1995) and also as a beneficial counterpart for quantitative research (Brannen, 1992; Moran-Ellis et al., 2006). In relation to urban policy, qualitative methods have been positioned as having an ‘*undeniable advantage*’ if the research question is of a ‘*how*’ or ‘*why*’ nature (Maginn, et al., 2008, p. 14). Due to the complex nature of vibration and potential difficulties in articulating attitudes, sensations, and perceptions of vibration, a qualitative methodology could help unravel and explore the human response to vibration in residential environments (Condie & Brown, 2009).

An in depth qualitative approach was beyond the scope of this research, particularly as one of the central aims was to establish exposure-response relationships between vibration and annoyance. However, within the social survey questionnaire, a number of open questions were included. As qualitative open-ended questions have been included within the social survey questionnaire, much more information about ‘how’ people respond to vibration and ‘why’ respondents’ give a particular rating of annoyance can be further understood. The qualitative open-ended questions can therefore be used to interpret the exposure-response relationship and potentially further understandings of outlying case studies (e.g. a respondent with low annoyance ratings and high vibration exposure).

2.11 SOURCE-SPECIFIC ISSUES

The differences between the social survey questionnaires source-specific sections to measure human response to vibration from railway, construction and internal sources were kept to a minimum, optimizing the comparability of the data over different sources of vibration. Differences occur within source-specific sections on vibration and noise annoyance, definitions used for the sources of vibration under specific investigation (see Section 2.7.5 for more detail), and time frames within which respondents’ were asked to rate their level of annoyance.

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As construction activity was likely to be of a temporary, short term nature within the residential environment, *'in the last 12 months or so'* was unsuitable. Comparisons can still be made between the sources, however the defining characteristics which differentiate sources of vibration (e.g. temporary/permanent, short-term/long-term, emerging/established) should be noted. Those living near construction activity were asked to rate their annoyance *'for the duration of the construction activity'* in the source-specific sections (section H and I – See Appendix 2) to account for the often temporary nature of construction activities within the residential context. In the general sections D and E, respondents were asked to give their responses within the time frame of *'thinking about the time you have been living here'* as construction could not be specifically mentioned by the interviewer at this point without revealing the main focus of the research.

2.12 GATHERING INFORMATION TO SUPPORT THE MEASUREMENT OF EXPOSURE

The social survey questionnaire was just one of the two components of the research methodology. In designing the questionnaire, it was deemed important to consider the research methodology holistically and ensure that the data collected supported and reflected the requirements of the measurement of exposure. As such, the social survey questionnaire collected data on a range of different phenomena which supported the vibration measurement aspect of the research methodology (see Technical Report 1). For example, questions about where vibration was felt, heard or seen the most was recorded to aid the measurement of vibration exposure.

3 FIELD METHODOLOGY

This section provides an insight into the field methodology employed in this research. The preliminary field trial carried out with residents living near railways, and the pre-, on-, and post- social survey procedures are outlined with the intention to provide knowledge and guidance as to what carrying out such research entails for others wishing to carry out research on response to vibration in residential environments.

3.1 FIELD TRIAL STUDY

The preliminary field trial of the social survey questionnaire, involving 33 interviews with residents' living near railways, was undertaken in order to pilot the social survey questionnaire, thus allowing for any changes to be made before the main study began. A total of 349 properties were included within the sites identified. Those properties where there was

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no response were revisited no more than three times for the preliminary field trial. A total of 57 residents answered their door (16.3%), of whom 33 agreed to take part in the social survey (58% total response rate).

The preliminary field trial also provided the opportunity to test the field methodology and trial participant recruitment strategies to increase the study's success rate. For example, during the preliminary field trial, leaflets were distributed with the intent to increase awareness of the study and of interviewers being in their area. Many of the respondents, upon first face-to-face contact, were already aware of the study due to the leaflets distributed. Therefore this method was used throughout the research to maximise the response rate. Such efforts go towards the aim of obtaining a statistically robust and representative sample.

3.2 PRE SURVEY PROCEDURES

This section addresses the preparatory work that was carried out before interviewers arrived on site to carry out social survey questionnaires with residents.

3.2.1 RESEARCHER SAFETY PROCEDURES

A researcher safety protocol was put in place and was adhered to by the social survey research team. In the case of lone working (i.e. one researcher at one site) detailed guidance was provided on ensuring that relevant colleagues were, at any time, aware of their whereabouts. When working in pairs or teams at a site the researchers informed the person they were with as and when they entered or left a residence. Furthermore, as a collective team, researchers routinely contacted the team leader who was not on site, to ensure somebody at the university base had the relevant information as to where the field researchers were. When researchers were finished for the day they informed the team leader when they were leaving site, and when they arrived back home or at pre-arranged accommodation.

3.2.2 INTERVIEW CONDUCT AND TRAINING PROCEDURES

The importance of listening attentively and responding effectively to the information provided by respondents was highlighted in the interviewer training sessions provided to each member of the social survey team before they carried out any field work. Effective responses to the information given and a confident ability to deal with the variety of different situations that may arise during the interview process were covered in order to increase the engagement of the respondents in the interview process and subsequent agreement to internal vibration

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measurements being taken at the respondent's residence. Interviewers were trained to deliver the social survey questionnaire in a standardised, scripted way in order to improve the reliability and consistency of the data collected.

3.2.3 *SITE IDENTIFICATION PROCEDURES*

Sites were identified by the vibration measurement team and as such site identification is covered in more depth in *Technical Report 1 – Determination of Exposure*.

The vibration measurement team identified sites based upon their inclusion criteria (e.g. distance from source) whilst also taking into consideration the inclusion criteria of the social survey team (e.g. density of properties, different tenure types). Once a number of sites were identified (in close proximity to one another to increase response rate), they were discussed by the whole team to determine their viability in terms of the number of potential respondents at the site, the possible placement of accelerometers for control positions at the site, and also the proximity to other sites nearby.

Before the social survey team commenced fieldwork at a site, two research team members conducted a site reconnaissance to ensure the suitability and viability of the site, and to identify any potential issues or difficulties that the social survey researchers may encounter on site. The site reconnaissance information was then communicated to the relevant social survey researchers before they commenced fieldwork.

3.2.4 *DETERMINING INTERNAL CONSISTENCY ACROSS INTERVIEWERS*

An in-depth training package was developed specifically for this project and was used to train and prepare field researchers to administer the social survey questionnaire. The training covered:

- Procedures regarding professional conduct when on site;
- Implementation of the survey (both from a technical point of view and also from a respondent engagement point of view):
- Ethical issues related to the research project;
- Health and safety procedures for work carried out in the field; and
- Training to enable the researcher to identify potential sites that could be considered for inclusion in data collection.

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The training also included a guide for the delivery of the social survey questionnaire which outlined how the social survey questionnaire acts as a script and should not be deviated from during the interview process in order to ensure internal consistency and the collection of reliable data across a number of interviewers.

Questionnaire scripting and routing were important components in ensuring that the social survey questionnaire was carried out consistently over a number of interviews. Where respondents do not understand the question, interviewers were instructed not to place their own meanings on the questions, which could result in the interviewers' interpretations of the questions influencing the responses given. If a respondent did not understand a question, or could not decide on a rating for example, the interviewer was instructed to pass over the particular question and record the data as missing.

3.2.5 QUESTIONNAIRE ADMINISTRATION

Part of the interviewer training focused on ways to successfully engage respondents to participate in this research. It was essential that the face-to-face interview was a positive experience for every resident who agreed to take part in the research, in order to increase the number of respondents who agreed to the later collection of vibration measurements for the 'exposure' component of this research project. The development of rapport and trust between the researcher and respondent throughout the interview process was essential as the respondent was required to provide their contact telephone number for vibration measurements within their property to be made. For an analysis of the success rates for this research (per source) see *Technical Report 5 – Analysis of the Social Survey Findings*.

3.2.6 DATA INPUT

Each day of fieldwork consisted of the details of the previous day's interviews being inputted into a spreadsheet which was stored in a shared computer drive accessible only by members of the research team. This spreadsheet consisted of only the necessary information required by the vibration measurement team. The entries stated the code number of the interview, formulated by the initials of the interviewer, the date, and the interview number of that day (e.g. JC12110901 – Jenna Condie, 12/11/09, Interview 1 of the day), and the respondent's name, address, and phone number when respondents agreed for vibration measurements to be taken at their property. In the latter case, the social survey team inquired as to the most convenient times for measurements to take place. This information was also included in the spreadsheet. Within the file, a column was also included to note when a site was finished and therefore when the vibration measurement team could commence their fieldwork there. This

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spreadsheet ensured communication between the two teams to assist the efficiency and effectiveness of the field work carried out.

The data collected in the social survey questionnaire was inputted and stored within an SPSS dataset. Each of the three sources investigated had their own SPSS dataset. The database contained all the data from the social survey questionnaire except for any personal information which could compromise a respondent's anonymity such as name, address, and phone number. In order to reinforce the confidentiality of the respondents, they could be identified in the SPSS dataset only by the assigned unique interview code. The data input was subject to quality control checks to ensure the consistency and accuracy of the SPSS dataset.

3.2.7 CO-ORDINATION OF VIBRATION MEASUREMENTS AND SOCIAL SURVEY

In the preliminary field trial, the two teams (social survey team and vibration measurement team) worked on site simultaneously. Although this approach was more successful in terms of gathering full case studies (i.e. both social survey questionnaire and vibration measurement data), it was time consuming in practice in terms of generating large numbers of case studies. Furthermore, there was a risk that respondents would see the vibration measurements team in their residential area which compromised the need to introduce the survey as one of neighbourhood satisfaction. The more successful approach was for the social survey team to complete the interviews on a given site and then the vibration measurement team would visit the site.

3.3 ON SITE SURVEY PROCEDURES

This section outlines the on-site survey procedures in terms of interviewing, the social survey questionnaire pro-forma, the respondents' agreement to allowing internal measurements to be taken at their residences, and the suitability of the data collected.

3.3.1 SURVEY IMPLEMENTATION

At each site, on the first day in the area, the social survey researcher familiarised themselves with all of the sites within the location in order to attain a better understanding of the area, after which the researcher began knocking on doors to engage people in the research. Usually larger streets that had a greater number of properties (e.g. long rows of terraced houses) were targeted first. This strategy was taken to support the vibration measurements team who required a large number of interviews carried out in properties of close proximity to one another for successful control positioning of the accelerometers (for further information see

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Technical Report 1 – Measurement of Exposure). Each property within the site was then visited up to three times in the attempt to carry out a social survey questionnaire with the resident. Properties were revisited if there was no-one home or if interviewers were asked by the resident to come back at a more suitable time. If the occupier was home but it was not a convenient time for them, the researcher made a diary appointment for a later time or date that was more suitable for the respondent.

3.3.2 INTERVIEWING

The social survey questionnaires were either completed on the doorstep or inside residences, depending on the respondents' preference. When carried out on the doorstep, Section Z (Interviewer Assessment of Vibration and Noise) of the questionnaire was not completed. In relation to the interview timing, this was largely dependent upon whether the respondent reported being bothered, annoyed or disturbed by the vibration and/or noise from the source and the corresponding source-specific sections that they were asked to complete.

Once the social survey questionnaire had been administered, respondents were debriefed as to the aims of the project. The debrief statement was included at the end of the social survey questionnaire and interviewers were trained not to deviate from this statement.

At a suitable and appropriate time and place (i.e. away from the respondent's property and neighbouring properties) the researcher completed two sections of the social survey questionnaire that were to be completed by the researcher alone and not with the respondent. The two sections were: Section A - Dwelling Information, which contained questions about the dwelling and surrounding area, and Section Z - Interviewer Assessment of Vibration and Noise, if the social survey questionnaire was completed within the property.

3.3.3 SOCIAL SURVEY QUESTIONNAIRE PRO FORMA

When on site, each field researcher kept a log or interviewer sheet with details relating to each property within the site. The researcher kept details as to when they attempted to interview the resident of the property, the number of call-backs (maximum of three times), whether an interview was achieved or not and whether a non-response sheet was completed with the resident. This was to ensure interviewers did not knock on doors where an interview had already been completed or where residents did not want to take part in the research. The interviewer sheets also enabled a different researcher to go to a previously attempted site to carry out field work.

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3.4 POST SURVEY PROCEDURES

This section outlines the post survey procedures in place that ensure internal consistency of social survey data collection across a number of interviewers and the administration procedures involved in the handling and management of the social survey data. In addition, the procedures in place to ensure effective communication between the social survey and vibration measurement teams, the co-ordination of data collection and data analysis of the social survey and vibration measurement data, are also outlined with regards to data inputting processes.

3.4.1 *QUALITY PROCEDURES*

In order to ensure that the interviewer carried out the social survey questionnaire correctly, when completed questionnaires were returned to the office base, they were checked for quality by the social survey project lead. For the data input process, the SPSS dataset was also subject to quality checks to ensure data was inputted correctly and consistently, and that missing data was dealt with accordingly.

3.4.2 *DATA INPUT*

When the social survey questionnaires were returned to the office base, the respondent information required by the vibration measurement team was inputted into the spreadsheet as soon as possible to keep a continuous update of sites and also to keep an update of the total number of social survey questionnaires carried out. Twice a week, the system was completely updated before midday so that the vibration measurement team could use the information to make arrangements for taking internal vibration measurements at respondents' properties.

3.5 IS THE DATA SUITABLE TO DETERMINE EXPOSURE-RESPONSE RELATIONSHIPS?

The following section discusses the suitability of the data collected by the social survey, and the success of respondent comprehension of the questions and response scales within the survey.

The five-point semantic and eleven-point numerical scales were implemented consistently throughout the social survey in order to gather the data required on respondents' vibration and noise annoyance. The interval-level measurement scales provide social data needed for

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the statistical analysis with the objective measurements of vibration in order to determine an exposure-response relationship between levels of annoyance and levels of vibration in residential environments. For further discussion see *Technical Report 6 – Determination of Exposure-Response Relationships*.

4 DISCUSSION

For the purposes of developing international standards and policy guidance for vibration in the residential environment, a social survey questionnaire can provide the data necessary for establishing acceptable levels of vibration exposure, and predicting self-reported levels of annoyance of exposed residents. The social survey questionnaire has been developed in order to achieve the main aim of this research: to establish exposure-response relationships for vibration in the residential environment. This technical report also aims to provide enough detail to assist other research projects in social survey development and field methodology. Copies of the social survey questionnaires with vibration and noise source-specific sections for railway, construction activity, and internal sources are also included in the appendices (see Appendix 1, 2 and 3).

Previous research, best practice guidance, and international standards for socio-acoustic survey design heavily influenced the development of the social survey questionnaire, to ensure that the questionnaire would meet the criteria established (see section 2.3 – The social survey questionnaire). With these criteria in mind, the social survey questionnaire developed provides suitable data, and has used the response scales that will most likely be adopted internationally, to assist future comparisons of the findings with other vibration research. However, it should be noted that other response scales could have been used successfully to explore the response to vibration in residential environments. As such, further research is still required on vibration annoyance response scales. To give examples, could one response scale be used rather than two (five-point semantic and eleven-point numerical); how does the five-point semantic scale compare to a seven-point semantic scale; and how might a semantic differential scale be used to explore vibration in residential environments?

The limitations of the social survey questionnaire as a quantitative method of investigation should be recognised and acknowledged. A socio-vibration survey can be '*employed to find the link between the source of vibration and the psychological response people exhibit*' however other approaches, from a more qualitative tradition, can '*help us to learn more about the link itself*' (Condie & Brown, 2009, p. 63).

A social survey method is one of many possible ways to collect data on the response to vibration. More longitudinal methods such as diaries and repeat interviews could provide a more in depth account of vibration in the home. Qualitative research methods such as semi-structured interviews could also be implemented to further understand human response to vibration in residential environments. Although such data is not suitable for the

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determination of exposure-response relationships, it can be used to support and further explain the relationships found. The benefit of adopting qualitative methods to support and understand quantitative data is already well established within the social sciences. The qualitative and contextual data collected via the open questions of the social survey questionnaire could be used to explain those cases which out lie the exposure-response relationship.

Although the annoyance approach is useful for developing policy guidance and standards, caution should be taken when focusing on annoyance as the main measurement of response. The response to vibration is much wider, and goes beyond annoyance. It is important that research explores other psychological concepts and social factors such as sensitivity (Miedema, 2007), and other attitudinal factors (see Guski, 1999). How we respond to vibration has been found to be influenced by a wide range of factors, some of which have been accounted for within the social survey questionnaire such as socio-demographic variables (e.g. age, gender, employment etc), sensitivity to vibration and noise, acceptability of vibration and noise, expectations of vibration and noise in the future, plans to move, length of residency, tenure, and neighbourhood and home satisfaction. Such factors provide data that supports a more comprehensive understanding of annoyance (see *Technical Report 5 – Analysis of Social Survey Findings*) and also assists in the determination of exposure-response relationships (see *Technical Report 6 – Determination of Exposure-Response Relationships*).

As vibration annoyance research has a tendency to follow the examples set within noise annoyance research, it may be useful to explore the growing body of knowledge on soundscapes research. The soundscape concept has been drawn upon in recent times due to its potential to rethink noise evaluation, noise annoyance, exposure-response relationships, the effects of noise, and the relevance of the social context in which noise (or sound) is experienced (Gifford, 2007; Schulte-Fortkamp & Lercher, 2003). Many soundscape research studies have explored both the positive as well as the negative sounds within residential environments (Raimbault & Dubois, 2005; Schulte-fortkamp & Fiebig, 2006): a rather different approach to that taken in noise annoyance research.

Although it is recognized that vibration is largely unwanted and has implications for a building's structure, a more neutral holistic 'sensescapes' approach may provide useful understandings of vibration in the residential environment. As discussed earlier, Fields and Walker (1982) critiqued the British Railway Survey (1975) for not including a positive rating option for people to give with regards to railway noise. Such findings may also be applicable to vibration within the residential context. Soundscapes research has also emphasised the essential role of the context within which sounds are heard, the localised nature of sound production, the importance of individual experience, and what sounds are expected, wanted, and accepted into our everyday sound environments (see Defra, 2009 for a review). The range of quantitative and qualitative methods and tools used within soundscapes to understand resident evaluations of their sound environments could also be used to explore the complexities of the sensory experience of vibration in residential environments.

5 CONCLUSIONS

The social survey questionnaire has been designed to gather the measurement of ‘response’ for the determination of exposure-response relationships for vibration in the residential environment. The social survey questionnaire allows for an in-depth analysis of annoyance by collecting annoyance ratings on five-point semantic and eleven-point numerical scales for all potential sources of vibration and noise in the residential environment, source-specific annoyance responses for railway, construction activity and internal sources, and annoyance ratings during the day, evening, and night. This data is suitable for analysis with vibration measurement data. Other questions around and beyond annoyance are included to gather information on the respondents’ characteristics, satisfaction with their neighbourhood and home, vibration and noise sensitivity and acceptability, and open questions to gather contextual information about the source in question. The open questions potentially provide valuable data that would otherwise be missed or overlooked.

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6 REFERENCES

- Arnberg, P. W., Bennerhult, O., & Eberhardt, J. L. (1990) Sleep disturbances caused by vibrations from heavy road traffic, *The Journal of the Acoustical Society of America*, 88(3), 1486-93.
- Bonnes, M., Bonaiuto, M., & Ercolan, A. (1991) Crowding and residential satisfaction in the urban environment, A contextual approach, *Environment and Behavior*, 23(5,) pp. 531-552
- Brannen, J. (1992) *Mixing methods: qualitative and quantitative research*, Surrey: Ashgate
- Brooker, P., Critchley, J., Monkman, D., & Richmond, C. (1985) *United Kingdom aircraft noise index study (ANIS): main report*. London
- Cawthorn, J., Dempsey, T., & Beloach, R. (1978) Human response to aircraft-noise-induced building vibration, *Helicopter Acoustics*, 2, pp. 479- 491
- Condie, J., & Brown, P. (2009) Using a Qualitative Approach to Explore the Human Response to Vibration in Residential Environments in the United Kingdom, *The Built & Human Environment Review*, 1(2), pp. 58 - 68
- Day, R. (2007) Place and the experience of air quality, *Health & Place*, 13, pp. 249-260
- Defra (2007) *Human response to vibration in residential environments (NANR172)*, London: Department for Environment, Food and Rural Affairs
- Defra (2009) *Research into the Practical and Policy Applications of Soundscape Concepts and Techniques in Urban Areas (NANR 200)*, London: Department for Environment, Food and Rural Affairs
- Fields, J., De Jong, R., Gjestland, T., Flindell, I., Job, R., Kurra, S., et al. (2001). Standardized General-Purpose Noise Reaction Questions for Community Noise Surveys: Research and a. *Journal of Sound and Vibration*, 242(4), pp. 641-679
- Fields, J. M., & Walker, J. G. (1982) The Response to Railway Noise in Residential Areas in Great Britain, *Journal of Sound and Vibration*, 85(2), pp. 177-255
- Gifford, R. (2007) Environmental Psychology and Sustainable Development: Expansion, Maturation, and Challenges, *Journal of Social Issues*, 63(1), pp. 199-212
- Griffin, M. (1996) *Handbook of human vibration*, London: Academic Press

NANR209 Technical report 2: Measurement of response

Grimwood, C. J., Skinner, C. J., & Raw, G. J. (2002) *The UK National Noise Attitude Survey 1999/2000*, London

Guski, R. (1999) Personal and social variables as co-determinants of noise annoyance, *Noise & Health*, 3, pp. 45-56

Guski, R., Felscher-suhr, U., & Schumer, R. (1999) The concept of noise annoyance: how international experts see it, *Journal of Sound and Vibration*, 223(4), pp. 513-527

Herranz-Pascual, M. K., Eguiguren-Garcia, J. L., Rocio Proy-Rodriguez, N. T., & Aspuru-Soloaga, I. (2009) Structure Borne Noise and vibration from rail infrastructures: a methodological proposal for the assessment of social impact, *Euronoise 200*, Edinburgh

Howarth, H., & Griffin, M. J. (2008) Development of a social survey questionnaire of reactions to vibration in residential buildings. *Acoustics 2008*, pp. 4317-4321

ISO (2003) *ISO/TS 15666:2003 Assessment of noise annoyance by means of social and socio-acoustic surveys*.

Klæboe, R., Ohrstrom, E., Turunen-Rise, I., Bendtsen, H., & Nykanen, H. (2003) Vibration in dwellings from road and rail traffic — Part III: towards a common methodology for socio-vibrational surveys, *Applied Acoustics*, 64, pp. 111-120

Landry, C. (2006) *The Art of City Making*, London: Earthscan.

Lee, P. J., & Jeon, J. Y. (2008) Soundwalk for evaluating community noise annoyance in urban spaces, *9th International Congress on Noise as a Public Health Problem (ICBEN) 2008*, Foxwoods, CT

Levine, N. (1981). The development of an annoyance scale for community noise assessment, *Journal of Sound and Vibration*, 74, pp. 265-279

Maginn, P.J., Thompson, S.M., & Tonts, M. (2008) Qualitative urban analysis: towards a pragmatic renaissance. In & M. T. P.J. Maginn., S.M. Thompson (Ed.), *Qualitative Urban Analysis: An International Perspective*. Oxford: Elsevier

Mansfield, N. (2005) *Human response to vibration*, Boca Raton: CRC Press

Meegan, R., & Mitchell, A. (2001). “It’s not community round here, it’s neighbourhood’: Neighbourhood Change and Cohesion in Urban Regeneration Policies, *Urban Studies*, 38(12), pp. 2167 - 2194

Miedema, H. M., & Vos, H. (1998) Exposure-response relationships for transportation noise, *The Journal of the Acoustical Society of America*, 104(6), pp. 3432-45

NANR209 Technical report 2: Measurement of response

Miedema, H. M. E. (2007) Annoyance Caused by Environmental Noise: Elements for Evidence-Based Noise Policies, *Journal of Social Issues*, 63(1), pp. 41-57

Moran-Ellis, J., Alexander, V., Cronin, A., Dickinson, M., Fielding, J., Slaney, J., & Thomas, H. (2006) Triangulation and integration: processes, claims and implications. *Qualitative research*, 6(1), pp. 45-59

Nordtest Method. (2001) *Assessment of annoyance caused by vibrations in dwellings from road and rail traffic by means of socio-vibrational and social surveys*, NT ACOU 106 Approved 2001-05

Osgood, C. (1975) *The measurement of meaning*, Illinois: University of Illinois Press

Ögren, M., Öhrström, E., & Jerson, T. (2008) Noise and vibration generation for laboratory studies on sleep disturbance, *Spectrum*, pp. 3-10

Öhrström, E., Gidlöf-Gunnarsson, A., Ögren, M., & Jerson, T. (2009) Effects of railway noise and vibration in combination: field and laboratory studies, *Euronoise 2009*

Parkes, A., Kearns, A., & Atkinson, R. (2002) What Makes People Dissatisfied with their Neighbourhoods? *Urban Studies*, 39(13), pp. 2413 - 2438

Pope, C., & Mays, N. (1995) Qualitative Research: Reaching the parts other methods cannot reach: an introduction to qualitative methods in health and health services research. *BMJ*, 311, pp. 42-45

Raimbault, M., & Dubois, D. (2005) Urban soundscapes: Experiences and knowledge, *Cities*, 22, pp. 339-350

Schulte-Fortkamp, B., & Lercher, P. (2003) The importance of soundscape research for the assessment of noise annoyance at the level of the community, *Techni Acustica, Bilbao*

Schulte-fortkamp, B., & Fiebig, A. (2006). Soundscape Analysis in a Residential Area: An Evaluation of Noise and People's Mind, *Acta Acustica United with Acustica*, 92, pp. 875 - 880

Schultz, T. J. (1978) Synthesis of social surveys on noise annoyance. *J. Acoust. Soc. Am.*, 64, pp. 377-405

Watts, G. (1984). *Vibration Nuisance from Road Traffic – Results of a 50 Site Survey*, TRRL Laboratory Report 1119, Transport and Road Research Laboratory

NANR209 Technical report 2: Measurement of response

Woodruff, H., & Griffin, M. J. (1987) *A survey of the effect of railway-induced building vibration on the community*, Institute of Sound and Vibration Research Technical Report No 160, University of Southampton

7 APPENDICES

Appendix 1: NANR209 – Human Response to Vibration in Residential Environments:
Railway specific questionnaire

Appendix 2: NANR209 – Human Response to Vibration in Residential Environments:
Construction specific questionnaire

Appendix 3: NANR209 – Human Response to Vibration in Residential Environments:
Internal sources specific questionnaire