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# FOREWORD

The Professional Practice Guidance on Gym Acoustics (ProPG 2 in the series) has been produced to provide practitioners and Local Authorities with guidance on a recommended approach for the standardised methodology for assessing buildings and environments for the location of a gymnasiums, fitness and exercise spaces (broadly referred to through the document as a 'Gym').

The ANC, IOA and CIEH have worked together, collaborating cross industry, to produce this guidance, which for the first time standardises an approach on assessing gym acoustics. The guidance is based largely on the experience and current state of knowledge of the Working Group at the time of writing. It is the intention to publish as electronically only, so updates to the guidance can be made periodically to include advances in knowledge and further validation in the future.

The Working Group includes a range of private practices, public body practitioners and manufacturers with many years of experience working with gym clients and dealing with planning applications. It is recognised that current Government regulations, policy and guidance sets clear objectives, but it does not attempt to prescribe specific numerical acoustic standards that assist practitioners to achieve them. The Working Group believes that the approach encouraged by this Professional Practice Guidance (ProPG) will be suitable in most situations likely to be encountered in practice, to allow for a number of different approaches to be used. It is hoped that the use and application of this guidance will result in a more consistent approach that will support the delivery of sustainable development and assist the location of gyms near residential, where this is appropriate and to identify where it is not. It is also intended to act as guidance for Local Authorities and to help identify where such development should generally be avoided, without extensive design considerations.

A high level of airborne and structure borne sound and vibration isolation is often only achievable by complex design methods that structurally isolate the noise generating activities. Good acoustic design can therefore enable the health and wellbeing benefits of a fitness and exercise space to exist near residential, whilst not adversely interfering with occupants' quality of life.

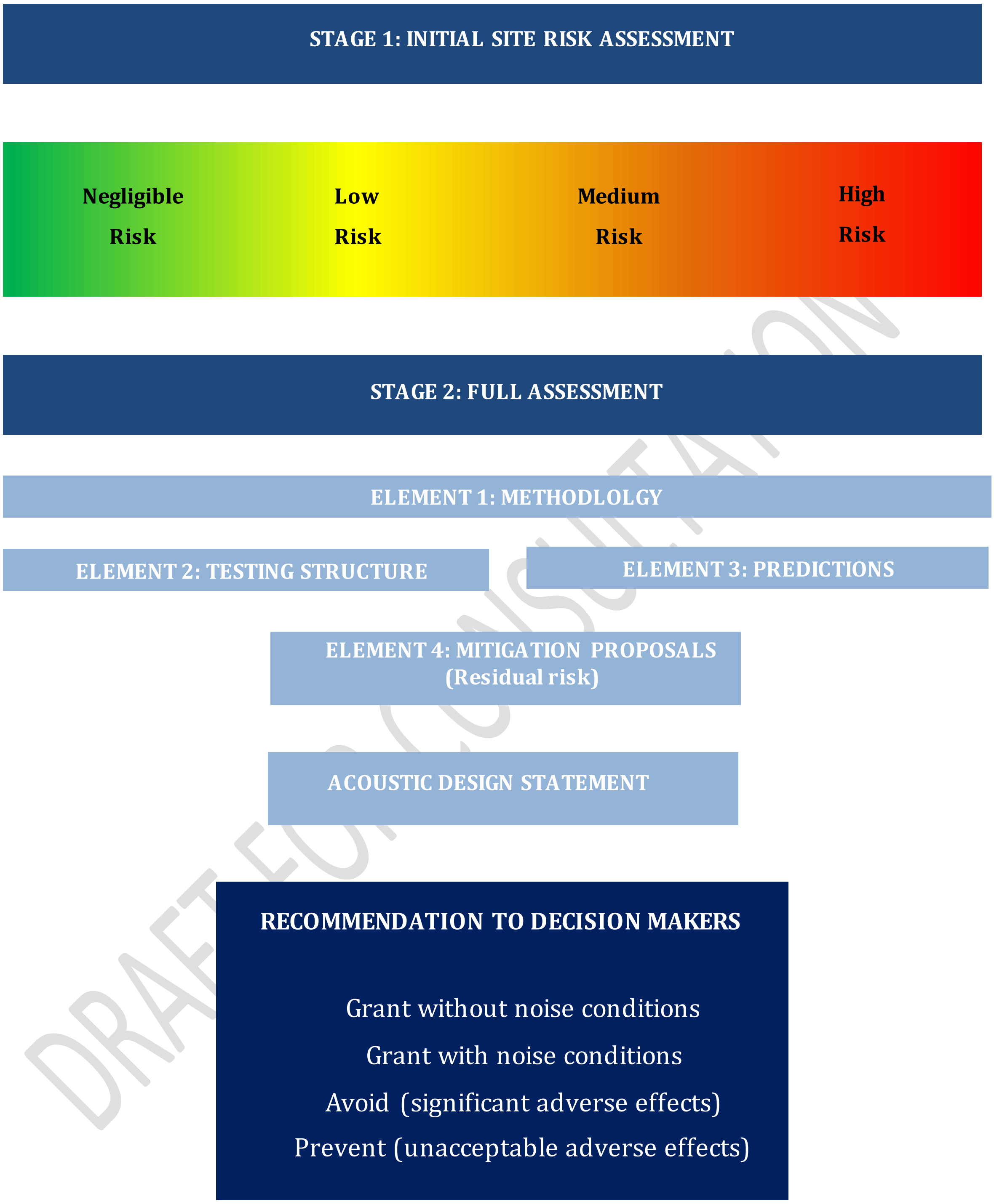
The National Planning Policy Framework (NPPF) encourages sustainable development, and the presumption to grant permission for residential development. The trend to place gyms close to where people live often means that residential is in close proximity and so the acoustic separation is an important consideration.

Building Regulations requires specialist advice to be sought between commercial and residential spaces. Suitably qualified acousticians (SQA) can provide this advice and the application of this guidance may provide one way to demonstrate this.

The recommended approach that is set out in the guidance includes a risk-based framework for practitioners to assess either an existing building, or a planned one. This is so situations where mitigation may not be required can be identified, and where it would be extremely challenging or not commercially viable that would also be recognised. Guidance on criteria has been offered to provide a useful starting point for a viability assessment. Criteria selection remains a matter for local determination, and a process is suggested to allow a robust position to be set out. Case studies have been included to show how the guidance could be applied.

*The Professional Practice Guidance does not constitute an official government code of practice and neither replaces nor provides an authoritative interpretation of the law or government policy on which users should take their own advice as appropriate.*

*Figure 1: Summary of overall ProPG 2 approach*



# 1. INTRODUCTION

## 1.1. Acoustics of Gymnasiums, Fitness and Exercise Spaces

The acoustics of Gymnasiums, Fitness and Exercise Spaces (referred to in this document as 'Gyms' for brevity) includes the consideration of airborne sound transfer, structure borne sound transfer and vibration resulting from the activities, people using the equipment, music systems and noise from plant. The impact as unwanted sound or noise (includes vibration that contributes to structure borne noise, or as perceptible vibration) at sensitive receptors. This is the subject of this guidance.

When considering a suitable location for a gym, the effect of the activities on sensitive uses nearby or within the same building is of importance. A suitably qualified acoustician (SQA) will be able to use this guidance to inform and standardise their approach and to inform their assessment and advice. This guidance will also aid engagement with the Local Authorities to assist to determine appropriate criteria to work to. Where mitigation is required, then the specifications of materials and systems can also be informed by this guidance. It may also assist operators by providing them with viable and optimal mitigation advice that achieves a sustainable operating environment.

For existing gym operations where new noise sensitive receptors are planned to come into existence, or have done so as part of permitted development, this guidance will be of assistance in informing the assessment and mitigation that would be needed to provide suitable living conditions. Where a new-build or proposed refurbishment of an existing building includes a gym structurally connected to existing residents then this guidance can also be used to help determine viability and what level of mitigation may be needed.

## 1.2. Planning Use Class

The Town and Country Planning (Use Classes) Order 1987 (as amended) puts uses of land and buildings into various categories, known as 'Use Classes'.

D2 Assembly and Leisure includes - Cinemas, music and concert halls, bingo and dance halls (but not night clubs), swimming baths, skating rinks, gymnasiums or areas for indoor or outdoor sports and recreation (except for motor sports, or where firearms are used).

**Changes to Use Classes from 1 September 2020 include:**

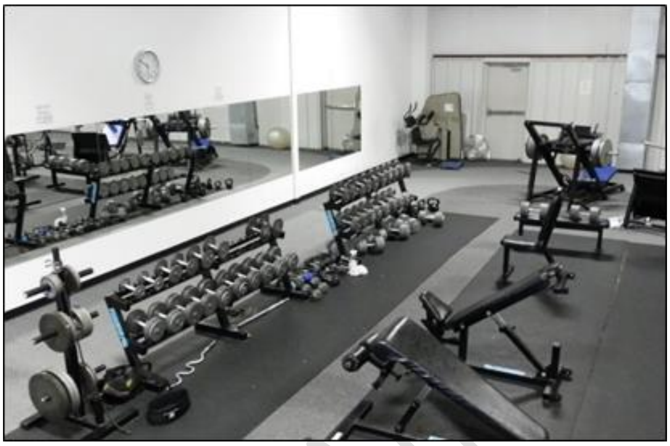
For purposes of Use Class, A1/2/3 & B1 to be treated as Class E:
E - Commercial, Business and Service

In 11 parts, Class E more broadly covers uses previously defined in the revoked Classes A1/2/3, B1, D1(a-b) and 'indoor sport' from D2(e):
E(d) Indoor sport, recreation or fitness (not involving motorised vehicles or firearms)
For any planning applications submitted before 1 September 2020, the Use Classes in effect when the application was submitted will be used to determine the application.

The implications of changes to the use class order are significant for proposals involving new gyms. Mixed-use lightweight structures that may, for example, have been suitable for office uses may not be acceptable for use as a gym, and, in many cases, this change of use will now be classed as permitted development without being subject to planning conditions. In these circumstances following technical guidance on acceptable standards for adjoining residential spaces is an important consideration.

For any reference to Permitted Development rights, and for restrictions to them or applications for Prior Approval, the Use Classes in effect prior to 1 September 2020 will be the ones used until the end of July 2021 (this is defined as the 'material period' in legislation so may be referred to as such).

## 1.3. Fitness and Exercise Spaces



**Fitness Gymnasiums (Gyms)** - Provides aerobic and body toning fitness exercises carried out using a range of specialised equipment. The Fitness Gym may be zoned into specific areas for stretching, cardio-vascular, resistance and free weight areas.

**Free Weights Area** - Dumbbell weights are normally stored on open racks grouped in weight ranges, with additional benches and stands provided for heavier barbell weights. Advice on layout will be site specific.

**Cardio Vascular Areas** - Would normally include a number of machines, each designed to provide a different form of exercise, arranged in a combination. The equipment may include the following: Tread or Running machines, Upper Body Ergometers, Fitness and Exercise, Cross trainers, Bicycles, Step machines, Rowing machines.

**Resistance Areas** - Exercise of specific muscle groups through the use of specialised equipment allowing controlled movement of part of the body against a resistance provided by hydraulics, counterweights, springs/bungee bands or friction. The equipment may be bulky and heavy, causing thuds when released.

**Cross Training** - Refers to the combining of exercises to work various parts of the body. It is a workout that includes cardiovascular and endurance exercise. Cross training is a "balanced" fitness program alternating exercises within the workout, or throughout the week, and may include use of slam balls or battle ropes.

**Stretch Area** - Used before and after exercise to allow muscular warm up and warm down stretching helping to reduce the risk of injury. Specific exercises may be advised for each part of the body, and include balance and floor work on padded mats.

**Pilates** - A low impact stretching activity and conditioning exercise that builds core strength within the body, improves posture & flexibility through small repetitive movements.

**Spinning** – A group of stationary upright bikes arranged around a central focus point. Exercise groups follow directions from an instructor. Spin bikes have fixed hubs requiring constant effort without coasting. Spinning classes often generate high noise levels, additional lighting and loud music to stimulate enthusiasm. Spinning classes can vary between small and large groups of twenty or more cyclists.

**Multi-Purpose Exercise Studios** – Studios accommodate a range of uses, allowing users to participate in a range of disciplines. Studios can accommodate exercise, dance & movement e.g. aerobics, sport training e.g. martial arts.

**Martial Arts Studios** – A wide variety of martial arts are practiced by all ages. They are practiced for fitness, development of combat and self-defence skills, self-cultivation/meditation, mental discipline, and character development.

**TRX** - Total Resistance Cross-training is a form of workout that is like Pilates, in that it involves static exercises and stretches using bodyweight (rather than metal weights), however typically involves hanging ropes from which the user pulls/balances.

**CrossFit** - Although no longer typically as popular amongst new gym operators in the UK, these types of studios produce substantially high impact forces into a building structure. The high intensity group training exercise classes combine aerobic exercises with repetitive power lifting of barbells and other heavy weights. It is not uncommon that during a Cross-Fit class, 50 kg - 150 kg barbells (depending on the participants' varying strengths) are repeatedly lifted above head height and dropped deliberately onto the floor/a mat. This would be considered onerous for just one user, but when considering an entire class of typically 5-20 participants, this can become acoustically problematic and requires substantial mitigation measures. It is rare for this type of studio/gym activity to occur or be viable within the same building that would also include residential dwellings.

**Weight Sleds**: Although the activity itself typically does not generate adverse impact levels (a sled with heavy weights is pushed or pulled across a long strip of carpet or fake grass), the acoustic risk arises when the user loads or stacks the weights onto the sled; typically, heavy 20+ kg disc weights are dropped onto the sled and/or the existing stack of weights already loaded onto the sled. This loading of the sled consequently imparts an impact force into the floor/structure.

**Vibration Training** - A concept that uses vibrations to enhance both strength and flexibility. The training works by utilising the body's natural reflexive response system. The user performs a series of exercises whilst standing on a 'vibration base plate'.

# 2. CRITERIA & GOOD PRACTICE

## 2.1. Relevant Noise & Vibration Assessment Standards and Guidelines

There are three approaches on which noise and vibration assessments can be carried out:

a) **Absolute Guideline Values** - The effects can be determined by reference to guideline values, for example BS 8233:2014 Guidance on sound insulation and noise reduction for buildings or BS 6472: Part 1: 2008 Guide to evaluation of human exposure to vibration in buildings.

b) **Change in Noise Level** - The effects can be determined by considering the change in noise level that would result from the noise source. This approach is contained within the Institute of Environmental Management and Assessment (IEMA) Guidelines for Environmental Noise Impact Assessment November 2014.

c) **Relative Effect** -The effects can be determined by comparing the resultant noise level after the noise source is placed into the local environment, against the background noise level ($L_{A90,\ T}$) of the area. This is the method employed by BS4142:2014 Methods for rating and assessing industrial and commercial sound and is used to determine the significance of effect.

The approach to assessment adopted by the SQA and Environmental Health Practitioner (EHP) can influence the effects that will ultimately be determined. It is considered necessary that liaison and correspondence takes place and any decision to adopt a particular approach is professionally supported, with a clear rationale and ideally agreement beforehand.

Guidelines and standards which have some relevance to the assessment and control of noise from Fitness and Exercise Spaces, but are not intended to be applied to assess sound from music or recreational activities include:

- **BS4142:2014** - Methods for Rating and Assessing Industrial and Commercial Sound provides a methodology for fixed plant and commercially related noise where the relative noise assessment can be applied in line with the scope. The objective is to determine relative noise impacts and quantify the effect of a specific noise, compared to the underlying background noise, in a given situation. Within fitness and exercise spaces noise from plant could be considered.
- **BS8233:2014** - Sound Insulation and Noise Reduction for Building, suggests absolute indoor ambient noise criterion for reasonable resting and sleeping conditions in bedrooms and living rooms, limited to anonymous noise over long durations.
- **NANR45**- Low Frequency (LF) Noise Assessment Protocol 2011, describes a method for measuring and evaluating LF noise against a set of one third octave band criteria from 10-160Hertz. The noise under consideration is then plotted against the LF annoyance criteria curve to ascertain if there are any dominant frequencies which require further investigation.

- Noise Rating (NR) Curves, proposed by Kosten & van Os (1962)
- Low Frequency Noise Rating Criterion (LFNR), Broner and Leventhall (1983) used research results to modify the NR curves in the low frequency region
- The threshold of hearing (see Figure 2 on page 14).

Table 1 below shows a summary of assessment metrics and guidance on target thresholds that exist in current standards:

*Table 1: Reference Assessment Threshold Ranges for Airborne and Impact Noise from current guidance or standards*

| | | |
|---|---|---|
| **BS8233** | Living Room/Bedroom (Day, 16 hours) | 35-40 dB $L_{Aeq,\,T}$ |
| | Bedroom (Night, 8 hours) | 30-35 $L_{Aeq,\,T}$ |
| | Lift noise in Bedroom (Night, 8 hours) | 25 $L_{Amax,\,F}$ |
| **Noise Rating NR ($L_{eq}$, $L_{max}$)** | Living Room/Bedroom (Day, 16 hours) | 20-30 |
| | Bedroom (Night, 8 hours) | 15-20 |
| **LFNR** | Living Room/Bedroom (Day, 16 hours) | 25-30 |
| | Bedroom (Night, 8 hours) | 20-25 |
| **NANR45** | Living Room/Bedroom (Day, 16 hours) | Above 1/3 Octave above LF criterion curve thresholds by more than 5dB in any 1/3 Octave band |
| | Bedroom (Night, 8 hours) | Above 1/3 Octave above LF criterion curve threshold in any 1/3 octave band |
| **BS4142 Relative Type Approach** | Living Room/Bedroom (Day, 16 hours) | Internal $L_{ArTr} - L_{A90,T}$ = 0 to +5 |
| | Bedroom (Night, 8 hours) | Internal $L_{ArTr} - L_{A90,T}$ = -5 to 0 |

*Note 1: In line with other assessment methods, such as BS4142 a level of +5dB above the $L_{A90,T}$ is indicative of an adverse impact and a level of +10dB or above indicative of a significant adverse impact, depending on the context.*

*Note 2: Structure borne noise contribution may generally form part of the overall noise contribution, and the above do not necessarily relate to structure borne criteria, apart from the lift noise within BS8233, which may be more stringent.*

*Note 3: These targets are not applicable for gym noise but provide an introduction only.*

## 2.2 Guidance on Noise Criteria

A good starting point for the selection of suitable criteria for airborne and structure borne noise, based on the working groups' experience, is set out in Table 2 below. Each case should be considered on this own merits however.

Good acoustic design will require the type of structure, and location to be properly considered.

It is recognised that the values in Table 2 will not be suitable in all settings, particularly where the background noise is low, or operational times continue into sensitive periods.

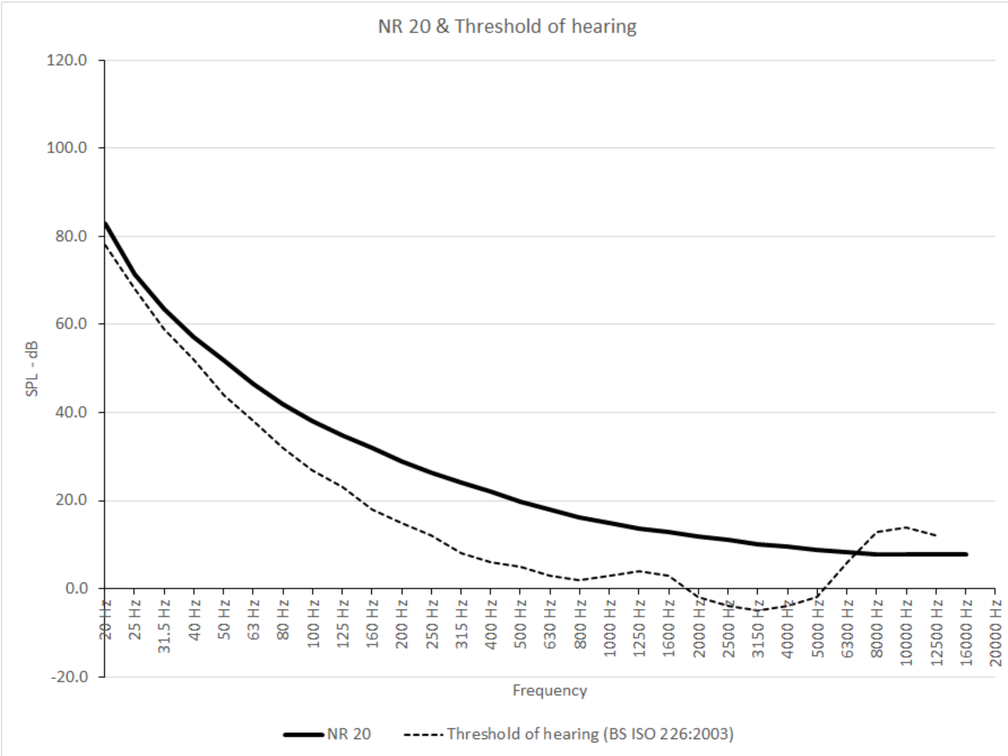
*Table 2: Example Planning Condition Noise Criteria*

| |
|---|
| **Airborne Noise**<br>Health and fitness activity noise shall be no greater than NR 20-25 $L_{eq,\ 5mins}$, as measured or predicted in any structurally adjoining habitable areas of residential properties located above or adjoining the health and fitness studio. |
| **Impact Noise**<br>Health and fitness activity noise shall be no greater than NR 15-20 $L_{max,\ 5mins}$, as measured or predicted in any structurally adjoining habitable areas of residential properties located above or adjoining the health and fitness studio. |

Notes:

1. *Ranges are presented as a guide for the criteria that may be appropriate, but each planning condition would require a scenario specific justification for the site concerned and may relate to different times of day. There may also need to be consideration of targets relative to background in certain frequency ranges, where background levels are low. The range therefore provides a guide for appropriate criteria.*
2. *Internal background noise levels in the properties during the most sensitive periods can be very quiet. In the case of 24 hour operations the criteria should be considered and fully justified.*
3. *For impact noise at least 1/3 octave bands analysis is desirable over the audible range from 10Hz;*
4. *For music noise particular care should be given to controlling noise in the bass frequencies, in the range 31.5Hz to 200Hz and $L_{max,\ F}$, $L_{1}$, or $L_{10}$ should be normally used as a parameter.*
5. *The threshold of hearing is defined in ISO 226:2003(en) 'Acoustics — Normal equal-loudness-level contours' and is helpful to define a guide for more stringent criteria, although these values are based on pure tone constant sound perception, and so will be likely to result in sound being audible for music or impulsive sounds which means that criteria may need to be less that these levels to be suitable in some scenarios.*

*Figure 2: NR 20 curve plotted against the ISO226:2003 Threshold of Hearing (Minimum Audible Field) for pure continuous tone perception of ontologically normal persons in the age range 18 to 20 years inclusively.*

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## 2.3 Discussion on Vibration Criteria

It is commonly the case when designing mitigation works to achieve appropriate levels of re-radiated structure-borne noise, that resultant levels of vibration within the receptor space will be imperceptible. As such, tactile vibration is usually a secondary concern after sound (or noise) when considering the effects of gym activity on occupants of neighbouring spaces.

Although instances are rare, it is nevertheless possible for tactile vibration to be the main, or a major, factor in the appraisal of a gym site or a developed acoustic control strategy. This section focuses on exploring some of those rare occasions.

Example situations that may occur include:

- Within neighbouring premises which operate with a relatively high level of ambient masking noise, such as a themed restaurant or bar.
- An unoccupied adjacency might house vibration-sensitive equipment.

- A receptor's floor structure which has a very low natural frequency and/or is poorly damped.

The acoustic practitioner will need to use their own knowledge and experience in providing advice but should also consider the various guidance and standards that are available.

This guidance does not attempt to address this, but the following discussion on guidance may be of assistance to highlight possible limitations in their application to gym activity.

**2.3.1 BS 6472: Part 1: 2008 *Guide to evaluation of human exposure to vibration in buildings. Vibration sources other than blasting* and BS 6841: 1987 *Guide to measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock*.**

BS6472 is the most commonly referenced document for vibration affecting residential and other building uses where human comfort is the prime consideration. Background to the document can be found in BS6841:1997. It is recommended that the acoustic practitioner is familiarised with both prior to embarking on any assessment.

BS6472 uses the Vibration Dose Value (VDV) parameter to assess the likelihood of adverse comment to continuous or repeated vibration over a daytime or night-time period. However it is questionable whether use of VDV is appropriate to assess the effect of gym activity because;

- The vibration dose summation procedure described in the standard allows for all types of vibration exposure to be assessed over a 16 hour for period daytime or 8 hour period for night time for continuous vibration sources primarily. It is considered by the working group this is not be suitable for gym site appraisals where transient or impulsive sources are typical and the number of impacts are variable;
- Estimation of VDV (eVDV) by combining individual measurements of acceleration is generally discouraged, unless no other means of determining VDV are available. This is because the calculation method is not reliable where the 'crest factor' (ratio of peak acceleration to rms) is greater than six. For transient or impulsive vibration sources, such as weight impacts, this is likely to be the case. VDV of impulsive vibration may not be helpful to rely on as a different response might be expected for each scenario;
- Although mainly dependent on the magnitude of vibration, duration of vibration is also a factor of VDV so for intermittent vibration, this would require an estimate to be made as to the number of events occurring in a daytime or night-time period, which is usually impractical. The working group do not suggest this approach is adopted.

Use of VDV for gyms offering free weights and pin machines, i.e. where discrete vibration events may be expected, could therefore result in the need for a complex assessment, which will require an agreed model of gym activity.

For a more robust assessment of discrete events, it may be preferable to relate received levels of vibration to the extent to which they can be perceived. For example, BS6841 states that 50% of the population can 'just detect' weighted vibration ($W_b$) with a peak magnitude of approximately 15mm/s$^2$, with the interquartile range extending from around 10 to 20mm/s$^2$. BS6472 notes that perception thresholds are slightly higher, i.e. people are less sensitive, for vibration of less than about one second duration and that a person is less likely to notice vibration if moving around compared to when still.

BS6472 suggests that, in non-residential situations such as offices, people are tolerant of twice the amount of vibration, as VDV. In a workshop environment, it suggests that people are four times as tolerant. As the VDV is determined primarily by vibration magnitude, these factors could be a consideration when assessing tolerance of discrete vibration events in such environments. Although issues such as hand control and visual blurring should not be ignored, it is noted that the onset of reported discomfort occurs at weighted rms vibration magnitudes of 315mm/s$^2$.

### 2.3.2 HTM 08-01

The Health Technical Memorandum (HTM) sets guidance for health care facilities and makes reference to BS6841, and may well be applicable to gyms within those facilities, or near to them. It recommends use of $W_g$ weighting with base value of 5mm/s$^2$, with multipliers of up to 8, i.e. up to 40mm/s$^2$, for non-critical areas.

It suggests that intermittent vibration in critical areas, such as operating theatres and precision laboratories, is considered against the limits set for continuous vibration. The same approach is to be adopted in other areas unless the duration and frequency of intermittent vibration is known, in which case assessment could be carried out as VDV as described in BS6472.

### 2.3.3 Specialist Equipment

Whilst the adoption of good acoustic design would typically avoid locating a gym next to an area housing sensitive equipment, such as high-resolution printers/plotters, electron microscopes and small component production, it is not inconceivable that instances could occur.

Such equipment is usually, or can be, provided with a bespoke isolation table or mount, allowing it to be installed in less-than-ideal situations. Manufacturers often supply specifications for the vibration environment within which sensitive equipment is to be installed and, if the type and model is known, this should form the basis of the assessment.

As is more often the case this detail is not known, and reference should be made to the widely published set of Vibration Criterion (VC) curves; a full description of these can be found in the ANC guide *Measurement & Assessment of Groundborne Noise and Vibration*.

As these are set for continuous vibration, comparison against peak levels of impulsive vibration would result in a robust approach to an assessment. The curves are presented in terms of vibration velocity. Additional care may need to be exercised in converting peak acceleration values into velocity. Simple approximation of the waveform to a sinusoid could introduce a significant level of uncertainty, and care should be taken.

### 2.3.4 Floor Response Factors

The Steel Construction Institute (SCI) has developed its own set of base curve multipliers, known as Response Factors, for use in designing lightweight or composite floors. These modify and supplement those set out in BS6472:1992 to reflect acceptance limits for continuous vibration in non-critical areas (note: this standard superseded by the 2008 version).

The base curves adopted are derived from rms acceleration of 5mm/s$^2$ (vertical axis) and 3.57mm/s$^2$ (horizontal axes). Weighting networks in the vertical axis are either $W_b$ where human comfort is of concern, i.e. as BS6472:2008, or $W_g$ where vision and/or hand control is more important, i.e. as BS6472:1992. The $W_d$ weighting network is to be used for vibration in the horizontal axes.

Multiplying (Response) factors are stated for the transient, albeit repeatable, event of a single person walking. For an office, a factor of 8 is recommended whilst, for a shopping mall, the value is 4.

# 3. TESTING METHODOLOGY

## 3.1. General

The following methodology should be applicable for both baseline and commissioning testing of all gym areas. In the following sections, various testing parameters will be explained, allowing for the methodology to accommodate proposed gym spaces used for varying uses (see Section 1.2).

Acoustic issues from gym activity can be summarised into one of the following groups (covered in Section 3.5 in more detail):

- **High Impact Response** (HIR) (e.g.: Impacts with hard/ soft masses)
- **Synchronised Repetitive Excitation** (SRE) (e.g.: Running on a treadmill)
- **Airborne Noise** (AN) (e.g.: Spinning Class Music)

It is understood that an Airborne Noise assessment can be assessed following other standard methodologies such as guidance given in BS EN ISO 16283-1:2014. However, for HIR and SRE analyses the following assessment methodologies are recommended to provide a standardised framework for assessments.

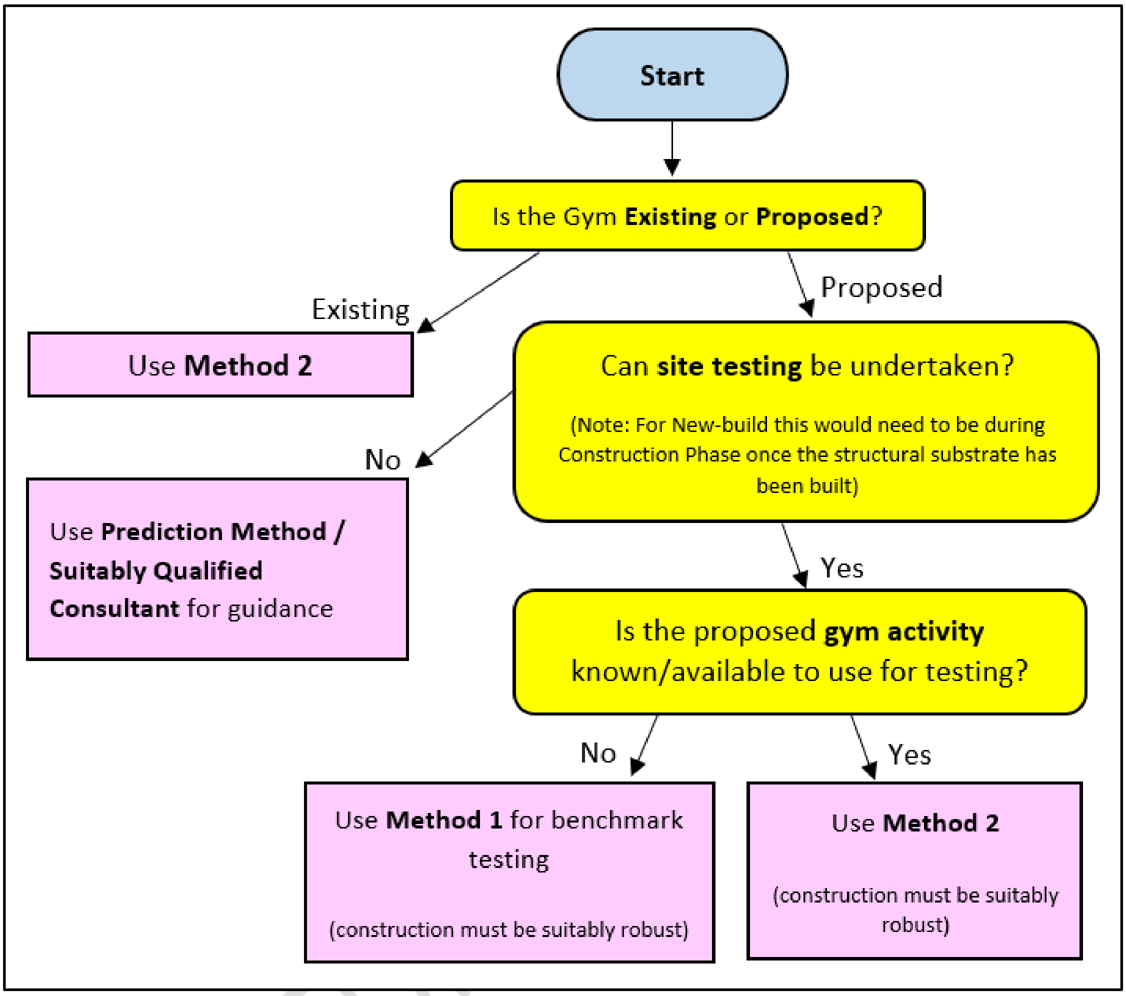
For HIR assessments, a single high-impact impulse can be generated by dropping or slamming of a heavy weight (e.g.: dumbbell/barbell/kettlebell/slam-ball/tractor tyre/ battle ropes), which is referred to in the following sections as a “weight drop” event.

In an ideal scenario, final commissioning of gym equipment could reasonably be undertaken by measuring the specific items of gym equipment being used by professionally trained gym users. However, in practical terms, this is usually not possible. What is usually the situation is an opportunity to undertake baseline acoustic tests prior to gym floor installation. This means a consistent assessment methodology is helpful. The results of such an analysis should form the objective part of the assessment process, which should also consider other subjective considerations (e.g.: how ‘noticeable’ the noise is subjectively).

## 3.2. Summary of methodology

The aim of the testing methodology is to simulate the source activity (HIR or SRE) in the proposed gym area(s) and measure resulting noise levels in the nearest sensitive receptors, which can then be assessed against the defined criteria.

*Figure 3: Flowchart to Determine Appropriate Gym Testing Methodology*



## 3.3. Equipment

### 3.3.1. Sound Level Meter

The Sound Level Meter (SLM) should comply with the requirements of accuracy class 1 defined in IEC 60651 and IEC 60804. The SLM should be calibrated before and after measurement using a calibrator compliant with accuracy class 1 defined in IEC 60942. Reverberation Time measuring equipment (where applicable) shall comply with the requirements defined in ISO 354.

### 3.3.2. Weight

To generate a source impulse through weight drops, the source 'weight' should:

**For Method 1 Testing:**

- Be selected with a mass that is suitable for exciting the structure to a point where a response will be achieved (or highest weight to be used by the gym if less than 35 kg*). This is typically between 20 to 35 kg dropped from a height of 0.5m. Maintaining an equivalent mass will allow comparison of data across different projects. The uncertainty becomes greater for lightweight structures, and Method 2 would be preferred.
- Be of a shape which will consistently impact the floor with an equal surface area. The normal way of achieving this would be to utilise a kettlebell with a rounded (or partially rounded) base, allowing for the generation of a consistent and repeatable impulsive force. If this is not practicable, then additional numbers of weight drops are advised to ensure that a typical worst-case can be determined from the measured drops.
- Have a rubberised finish.
- Method 1 excludes drops from 0.5m above 35 kg - Anything above this weight would be classed as Method 2 testing.
- Carry out a response factor test of the structure (see section 2.3.4)

**Note: If possible, mass selection used in Method 1 should be representative of typical proposed activity, which should be justified and may result in a limit on the use through planning condition restrictions and or a noise management plan.*

*Figure 4: Examples of typical weights for Method 1 testing*


**For Method 2 Testing:**

The purpose of Method 2 testing is to measure realistic anticipated /existing resulting noise levels from activity that is representative of the proposed gym activity in the space. Any proposed gym equipment can be used but this is likely to involve dropping heavier weights/barbells from greater heights etc. (See Appendix F for guidance on Health & Safety). Where possible, measures should be taken to prevent the testing method from damaging the building structure (e.g. bare or untreated floor surfaces).

Due to the variation in the way energy will be transferred into the structure for different activity types, Method 2 testing should ideally include assessment of one of each of the following activities (where these items are proposed or are expected to occur in a gym):

- **Slamball/Medicine ball/Weight bags**
  Slams using the heaviest proposed unit*, 'slammed' from head height (approx 1.5 m). If slamballs are proposed to be slammed on walls, this should be measured. Generally, the worst-case weight would be around 10 kg in that case.

- **Dumbbell**
  Drops using the heaviest proposed unit*, in line with drop methodology given in Method 1. Generally, the worst-case weight would be around 35 kg.

- **Barbell**
  Drops using the heaviest proposed unit*, in line with drop methodology given in Method 1. Typically, the worst-case weight would be around 150 kg.

- **Treadmill**
  Running on the treadmill at a setting representative of a fast run (around 10 km/h) with shoes and with a flat-footed running style. This should ideally be measured continuously for a minimum of 30 seconds.

- **Fixed Pin Weight Machines**
  Given that the weight is fixed in the machine, it is recommended that the weight bars are released to drop from a height of around 0.2m typically, the worst-case weight would be 50 kg (depending on the type of machine). Depending on the placement of such machines, a judgement would have to be made on site, to ensure the worst-case situation has been assessed, taking into consideration the maximum weight of different machines and their proximity to the noise-sensitive receptors.

- **Other**
  Significant bespoke activities should be assessed such as battle ropes, weight bags, tractor tyre flips etc.

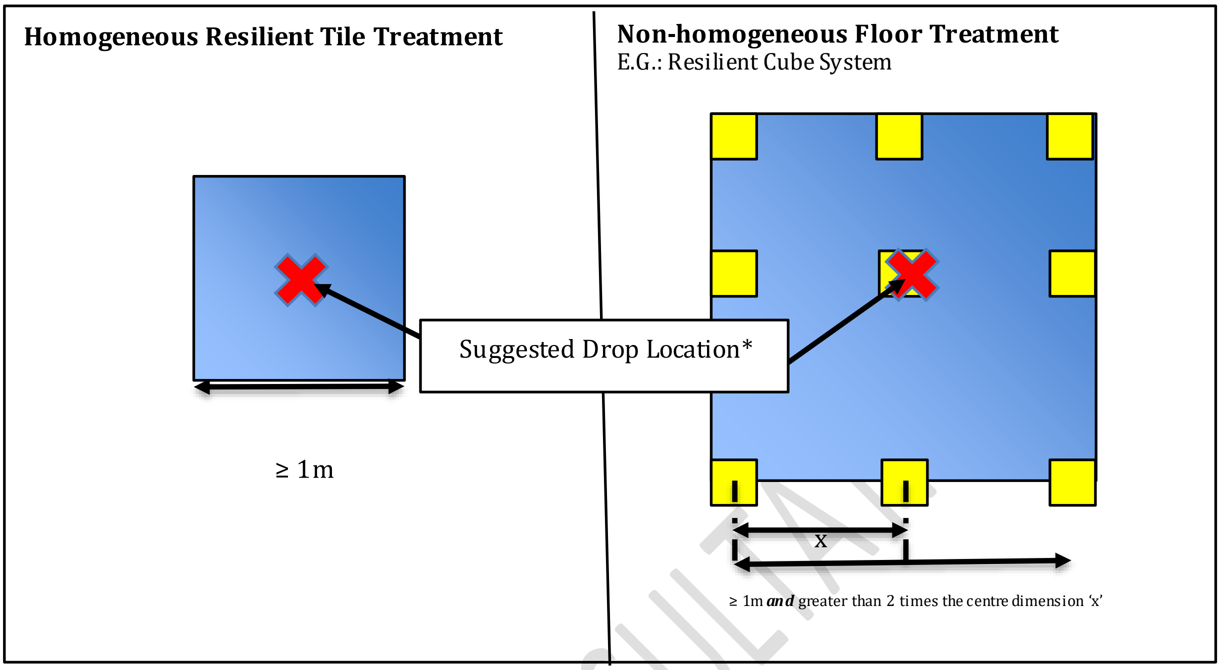
** Note that the 'heaviest proposed unit' may not necessarily be the heaviest weight available, particularly for units with interchangeable weights, however, should be representative of the typical upper limit used by the strongest/most experienced gym users. A view should be taken in consideration of guidance from the gym users and operators.*

### 3.3.3. Gym Floor Samples

If samples of flooring are being tested, these should ideally be a minimum of 1m x 1m in size to avoid the dropped weight rebounding onto the underlying substrate. Such dimensions are also required to ensure any deflection of the tile/treatment is representative of a wider sample.

For treatment types with 'centres' at larger dimensions (e.g.: resilient cube system at 1m centres) it is recommended that a sample which ideally covers twice this dimension is used, as shown indicatively in Figure 5, although it is recognised that this is not always practicable. The sample should have a performance largely equivalent to the fully installed floor system, however it is recognised that for floating floors, a small sample will not be fully representative of cavity damping effects. Selection of the sample should also take into consideration the required loading of the floor and substrate to achieve the desired frequency response. Suppliers and SQA's can assist with determining what is suitable, and that this will often represent a worst case.

*Figure 5: Indicative 'ideal' treatment sample sizes to be used for investigative testing*




*Note:*

1. *If the upper finish of the non-homogeneous floor treatment is broken into individual tiles, the drop position should not be on the separation between two tiles.*
2. *There can be an airborne contribution from a test rig and the acoustic excitation of other structures (such as unfilled soil pipes or toilet traps) which can affect the results in the test room and should be considered. Measurements of vibration can assist to identify and remove these elements.*

## 3.4. Test Area & Drop Positions

Depending on the size of the proposed gym area, a number of different 'drop positions' should be used as a guide. A minimum of 2 drop positions is recommended in all areas, however a judgement must be made on site to ensure enough positions have been selected to provide a representative sample of the floor performance.

In many cases it will be unrealistic to include a large number of tests on site and the Acoustician managing the survey should use suitable discretion to ensure the worst-case positions are included. Generally, these are adjacent to noise-sensitive areas and near to transmitting structures such as walls and columns (see guidance below).

The test area should also satisfy the following:

- be a minimum of 0.5m from any transmitting elements of the structure (e.g.: continuous walls/columns)

- At least one of the test positions should have a drop location at a distance of ≈0.7m from the expected worst transmitting elements (e.g.: continuous walls/columns). Care must be taken to ensure that any floor treatment being testing is not in direct contact with such adjacent transmitting element (thereby leaving a suggested gap of no less than 100mm between the edge of the sample and the structure). Note the drop position should still be a minimum of 0.5m from such structures, even if the edge of the sample is near to the structure.
- At least one of the test positions should be in a location where the potential for deflection is likely to be at its greatest. This will typically be centrally on the floor construction, however further knowledge/analysis of the tested structure may yield a more suitable location.

Note that any common airborne noise paths (e.g.: windows/doors/open service penetrations) should be closed/well sealed prior to commencing testing. If unsealed service penetrations or other weaknesses (e.g.: unfilled WC pipes) exist during testing, this is likely to compromise the robustness of the measured data.

## 3.5. Testing Methods

### 3.5.1. HIR Method 1 (Default)

Testing Method 1 aims to provide a minimum baseline methodology with a narrow weight range (20-35kg) to provide initial indication of site suitability (for untreated, pre-fit-out sites) and to avoid damage to untreated structures.

For each drop position a minimum of 3 drops should be measured, by dropping the weight from a height of 0.5m from the floor. Operatives should ensure that the drop height of 0.5m is measured from the finished floor level of any additional treatments which are added to the base floor construction.

The resulting noise (and vibration, if required) should be recorded during each drop. The exact times of the drops should be recorded to avoid error during processing of the data.

### 3.5.2. HIR Method 2

Testing Method 2 aims to provide guidance on additional "heaviest proposed unit" testing of proposed gym activity through the use of proposed equipment and real non-standardised weight drops. This testing is recommended to be undertaken by a trained member of fitness personnel (typically provided by the gym operator) who is capable of safely lifting/dropping weights/equipment from a greater height and in a more realistic way. Such results would not be comparable from one site to the next, however, should give individual users higher confidence in the proposed treatment system. HIR Method 2 would also typically be the default approach for investigative or diagnostic Acoustic testing, as site issues will typically be due to bespoke, site-specific activities.

For each drop position a total of 3 to 6 clean drops as a minimum should be measured, undertaking any proposed gym activity. Operatives must ensure that the drop height is accurately from the finished floor level of any additional treatments which are added to the base floor construction.

The resulting noise (and vibration, if required) should be recorded during each activity. The exact times of the drops should be recorded to avoid error during processing of the data.

### 3.5.3. SRE Testing Method

Synchronised Repetitive Excitation would typically occur in gyms where people are running/stepping together. Estimates of the response factor and complementary heel-drop tests as described in SCI P354 can assist to determine if the structural floor is dynamically sensitive to footfall excitation.

Walk-by or running (with flat-footed style) are ways to explore this, but it is the experience of the working group that this is not commonly done and is usually dealt with by a combination of the isolation within treadmills and also the floor treatment.

## 3.6. Noise Measurements

The field measurements of re-radiated impact noise due to impact in a gym floor should be made in one-third-octave bands covering an appropriate range, starting at a minimum frequency of 10Hz. Typically, much of the acoustic energy is in the low end of the spectrum, but the selection of the range should consider effects such as re-radiated sources like rattling lights, and amplified music transmission. Note that measurement of higher frequencies (e.g.: up to 10 kHz) may be useful to help identify background noise intrusion in measurements.

Measurement should be in a “full storage” mode with an integration time of 0.125s such that an accurate trace can be captured to be interrogated during the analysis.

The microphone should be a minimum of 0.7m from the floor height and 0.5m from any walls in the receiving room.

Where possible the reverberation time of the receiving room should be measured in accordance with ISO 354. These measurements could then be used, if required, to generate a correction term, if the receive area is expected to have a different RT (e.g. to cater for future use as residential).

A background measurement should also be measured when no weight drops are occurring. This can also be established from a single continuous trace by analysing the intervening measured levels between drops.

It is recommended that background noise levels are recorded directly before/after every set of measurements, especially if the measurement location is in use (e.g.: an active office space). Ideally the space when under test should be vacant, however it is common for complaint/investigative testing to be undertaken in occupied commercial/retail spaces, which cannot pause their operation. If this is the case, a longer background measurement should be taken and additional HIR/SRE events should be measured to provide a wider range of data for subsequent analysis.

## 3.7. Vibration

Tactile vibration has been discussed in section 2.3 and is usually a secondary concern to noise. Nevertheless, measurements within the receive space during weight drop testing enable the acoustician to decide whether tactile vibration may need to be considered further in their assessment or not.

Measuring the vibration response of the gym floor to an impulse excitation can be a useful diagnostic exercise. It can be used to determine the natural frequency, damping of the floor and the Response Factor of the structure (discussed further in Section 2.3.4).

Vibration measurements can also assist in assessment of structure borne noise, where temporary airborne flanking paths are evident between the gym and receiver location, at the time of the site visit.

Measurements of the RMS and/or peak acceleration should be carried out in one-third octave bands. The frequency ranges covered by weighting networks designed to address human response (ref. BS6472 and BS6841) and those of the Vibration Criterion curves are encapsulated by the minimum range 0.5Hz to 315Hz. If it has been agreed that the assessment is to be based on VDV/day/night the frequency of occurrence of each measured activity will need to be established. Vibration from impulsive events should be measured as VDV, but careful attention to the crest factor should be given.

The vibration transducer should be mounted and levelled at a position corresponding to the most-affected occupant, this typically being taken as the centre of the room. A secure connection should be established with the structure, for example by using a proprietary tripod baseplate or by other appropriate means that neither amplifies nor attenuates the vibration to be measured. It should be recognised that, where floors in a building utilise constructions of differing stiffness or mobility, the worst-affected receptor may not necessarily be the closest to the gym.

Much of the instrumentation currently on the market comprises three channels, allowing concurrent triaxial measurement. Where only single axis measurements are possible, preference should be given to obtaining data in the vertical (z-) axis, unless it can be shown that one of the other axes are dominant.

If undertaking measurements for a prospective gym in an existing building whilst in its shell state, i.e. prior to installation of finishes and furnishings, the vibration transducer will be placed on the structural floor. When assessing measured data, it should be recognised that vibration at frequencies above 10Hz may be attenuated by 'soft' furniture, such as chairs or beds, but that these may amplify vibration at lower frequencies. Similarly, soft floor coverings designed to satisfy the performance objectives set out in Approved Document E 2003 are unlikely to offer significant isolation against vibration in the range of frequencies that characterise human response.

It is useful to note that if suitable measures have been taken to control re-radiated noise, the vibration levels should not be perceptible at the receiver in most cases.

# 4. PREDICTION

## 4.1. Introduction

This section provides a simplified prediction methodology for noise (and vibration) generated from the action of falling masses upon floor slabs above. This may prove useful where it is not possible to complete on-site testing, which shall always be considered the preferred option due to the degree of uncertainties involved.

The justification of this section has come from the working groups experience of numerous occasions where testing cannot be undertaken, this method is therefore an approximation of noise transfer which could be used in the absence of site measurements.

The basis of prediction is sourced from textbooks widely available, and the reader is advised to visit works by Cremer, Fahy, Craik, Brunskog and Hopkins for background, theoretical reasoning and further detailed information. The latter reference follows a similar means of prediction to that which is presented in this guide, using Statistical Energy Analysis (SEA) as the computational framework.

It is important to note that the predictions stated herein shall be considered as an engineering-method for predicting an estimated response, rather than a precision method capable of values with low uncertainty. Advanced methods including fully coupled SEA, Transient SEA (TSEA), Finite Element Analysis and hybrid methods comprising mixed forms of prediction and/or experimental-and-prediction methods exist and will permit greater degree of accuracy, depending on the level of involvement and knowledge. It is acknowledged that such methods may not be practical, particularly where cost-efficient and time sensitive appraisals of gyms are required and, as such, this method is provided to give an approach that permits an order of magnitude indication of potential effects, the aim being to inform the level of mitigation that maybe required or illuminate any issues a candidate space may have in terms of feasibility.

The focus of prediction is for that of noise (and vibration) from gym activities on a suspended slab floor above a receiving room. Further guidance on vibration levels within the gym slab, the potential for transmission vertically and throughout a structure in addition to isolator considerations are not covered by the prediction method but are discussed further in the following sections.

## 4.2. Factors influencing uncertainty

It is important to appreciate that there are numerous factors which affect prediction accuracy, and these predominantly lie in the variability of the weight-drop source mechanism in-real world conditions. A non-exhaustive list of factors influencing vibration (and subsequently noise) from impact events is provided below:

- Mass of impactor (free-weight/dumbbell)
- Contact area between falling mass and floor surface
- Drop height
- Contact stiffness of the floor covering
- Material properties of floating and structural floor
- Structural dynamics
- Damping
- Properties of the floating floor system/resilient layer
- Flanking structural (or airborne) transmission paths
- Receiving-room acoustics

## 4.3. Limitations of SEA-based methods

The prediction method presented in this document is based on simplified SEA methods. SEA is often referred to as a high-frequency form of computation for vibro-acoustic transmission paths. The modelled system is divided into subsystems, with each subsystem assumed to have a sufficient number of modes in each band (octave, one-third octave etc.) making up the energy within it. Once power is injected into the subsystem (at one or more locations), the energy within connected systems can be calculated accordingly. It is and should be treated as a broad-brush technique and is best used to look at changes between situations.

One of the primary issues limiting use of SEA at low frequencies is the lack of modes within low-frequency bands, since isolated modes within a particular band do not best approximate the assumed evenness of energy within it. Consequently, users may find that the application of the method described herein is limited at low frequencies, particularly when undertaking calculations involving small rooms or small floors, since sufficient modes do not begin to develop until higher frequencies.

Noise within a receiver room is usually the primary area of concern. To review the potential for there being sufficient modes in a frequency range of interest room, the user can perform a modal check (assuming a box-shaped room) by first estimating the modal density of the space according to Equation 1 and then calculating the estimated number of modes $N_S$ using Equation 2.

$$n(f) = \frac{4\pi f^2 V}{c_0^3} + \frac{\pi f S_T}{2c_0^2} + \frac{L_T}{8c_0} \qquad 1$$

Where

$f$ is the frequency band of interest

$V$ is the room volume

$c_0$ is the speed of sound in air

$S_T$ is the total area of all the room surfaces

$L_T$ is the total length of all the room edges $4(L_X + L_Y + L_Z)$

$$N_S = n(f)B \tag{2}$$

Where $B$ is the bandwidth of the frequency band of interest.

Equation 2 can also be used as an input to estimate the degree of modal overlap between modes that exist within a frequency band of interest (Equation 3). Frequency bands with a value of $M < 1$ should be treated as highly uncertain. Values of than $M \geq 1$ are desirable as this indicates a smoother frequency response within the band considered. M will favourably increase with increasing frequency-bands due to more modes being present.

$$M = N_S f \eta \tag{3}$$

Where $\eta$ is total loss factor for the room, estimated as $2.2/(fT_{60})$ and $T_{60}$is the room reverberation time)

Similar checks can be made for structural elements (beams/plates) and the user is advised to seek these from the various texts if needed for each of the potential wave types that may be present within them. However, it is generally the case that floor modes have fundamental natural frequencies lower than room modes within the same space. As such, the mode count often increases to acceptable levels within frequency before the number of acoustic modes is also acceptable. As such, the above check is usually sufficient for establishing a frequency cut-off below which results become less certain.

## 4.4. Simplified Impact Model (Noise)

The simplified model for predicting third-octave band response is presented below as a series of steps. The steps described are for the prediction of noise in a receiving room directly beneath a gym impact. Guidance on predicting vibration and propagating through structures or alternative layouts is considered in Section 4.5.

**Step 1 - Establish force input**

Assuming lossless exchange of potential and kinetic energies, the velocity of a mass dropped from a height (h) will have a velocity at the point of impact.

$$v_0 = \sqrt{2gh} \tag{4}$$

For a perfectly elastic collision (where the impacting mass rebounds from the floor), and assuming a short duration impact, the magnitude of force produced is determined from Newton's 2nd law of motion, which can be rearranged integrated to determine the change in momentum and consequently express the peak force as

$$|Fn| = 2m\sqrt{2gh} \tag{5}$$

Where

$h$ is the drop height in metres

$g$ acceleration due to gravity 9.81m/s$^2$

For single impacts, the idealised spectral composition of Equation 5 is a series of spectral lines, positioned at 1Hz intervals. The RMS value is needed in each octave band which can be estimated using Equation 6.

$$F_{rms}^2 = \frac{|Fn|^2 B}{2} \qquad 6$$

Where $B = 0.23f$ for one-third octave bands with centre frequency $f$ or $B = 0.707f$ for octave bands

**Step 2 – Determine power injection into floor**

For heavy impacting masses, the impedance of both the receiving floor and the falling mass are required. The power injected into the floor is given by Equation 7

$$W_{in} = F_{rms}^2 Re\{\frac{1}{Z_{dp} + Z_m}\} \qquad 7$$

The above confirms that the power injection is proportional to the impedances of the source and the floor. If it is assumed that the plate is infinite, the driving point impedance of the floor, when excited in the central region, can be expressed using equation (5) and equation (6). It can be seen that the quantity $Z_{dp}$ can be readily derived using commonly available material property information needing only Young's modulus $E$, material density $\rho$, Poisson ratio $v$ in addition to the slab thickness $h_p$. The impedance of the mass, $Z_m$ is simply $i\omega m$.

$$Z_{dp} = 8\sqrt{B_p \rho h_p} \qquad 8$$

Where

$\rho$ = density (kg/m$^3$)

$h$ = plate/floor thickness (m)

$Bp$ = bending plate stiffness (Nm), given by (6) and noting that $E$ is the Young's Modulus of the plate (N/m$^2$) and $\upsilon$ is the Poisson ratio.

$$Bp = \frac{Eh_p^3}{12(1-\upsilon^2)} \qquad 9$$

For composite slabs where the thickness profile varies and the stiffness profile may orthotropic as opposed to isotropic, it may be acceptable to take the minimum-to-average slab thickness and compute a range of values to investigate sensitivity to such changes.

**Step 3 – Prediction of noise in a floor directly below impact**

Having derived the degree of power injected into a plate/floor, it is possible to estimate the energy levels in the floor and any connected subsystems. This guidance presents the use of SEA methods. For a single impact on a bare floor, this presents a simple 2-subsystem model with the floor acting as subsystem 1 and the receiving room as subsystem 2. Using SEA power balance equations and assuming negligible flow from the room back into floor, the energy in the room can be expressed as Equation 10

$$E_2 = \frac{\eta_{12}}{\eta_1 \eta_2} \frac{W_{in\{1\}}}{\omega} \qquad 10$$

Where:

$\eta_1$ = total loss factor for the plate/floor, estimated as 0.01 + $1/\sqrt{f}$ for bending wave motion within concrete structures

$\eta_2$ = total loss factor for the room, estimated as $2.2/(fT_{60})$ (where $T_{60}$ is the room reverberation time)

The quantity $\eta_{1,2}$ is the plate-to-room coupling loss factor, which can be expressed as Equation 11

$$\eta_{1,2} = \frac{\rho_0 c_0 \sigma}{\omega \rho_s} \qquad 11$$

Where:

$\rho_0$ = density of air, typically taken to be 1.21kg/m$^3$

$c_0$ = speed of sound in air, typically taken to be 343m/s

$\sigma$ = radiation efficiency of the plate/floor. For practical purposes, this may be set to a value of 1 for heavy masonry floors. Lightweight elements should be calculated separately using alternative calculation methods (Leppington *et al*, Maidanik).

From which the level in the room can be presented as decibels ($L_p$) re 2xl0$^{-5}$ N/m$^2$ as

$$L_p = 10\left(\frac{E_2}{E_0}\right) - 10V + 25.4 \qquad 12$$

Where:

$E_0$ = reference energy level 10$^{-12}$ J.

$V$ = receiving room volume (m$^3$)

It should be noted that the above method assumes an energy-averaged level of vibration within the radiating slab. In certain conditions, nearfield effects from the point of contact may contribute to the cumulative sound pressure level within a receiving room directly beneath point of impact, though in practise the method stated herein is usually sufficient. Further guidance on nearfield effects can be found in works by Cremer and Hopkins.

**Step 4 – Contact time corrections and estimation of $L_{max}$**

The prediction of noise in Equation 12 assumes that the contact period between weight and floor is infinitely small. In real-world conditions, the contact time as measured in seconds, $T_c$, will influence both the maximum observed force level in time (see Figure 6) and the spectral content in the frequency domain. Use of Equation 12 without correcting for contact-time effects will likely overestimate the sound pressure level if a comparison to commonly measured metrics, such as $L_{max}$ is required. For a more reliable $L_{max}$ sound pressure level estimate, it is usually sufficient to predict the response associated with a 100ms $L_{eq}$. This can be implemented in a straightforward manner via equation (10) below and setting $T_c$ to a value between 2ms and 7ms which is offered by the working group as typical of most impacts of this type, with sources matching those in the testing methodology section 3. This can be extended to provide $L_{eq}$ estimates for any time interval if required by substituting the 0.1 in Equation 13 for the time period of choice in seconds.

$$L_{max,est} = L_p + 10\frac{T_c}{0.1} \qquad 13$$

If an octave band level of performance is required, this can be determined in the usual manner by summing the appropriate bands.

The use of Equation 13 requires a limit on the frequency range which can be used in the prediction. This is particularly important in scenarios where an overall broadband level is required. The cut-off frequency at or above which third-octave bands are over predicted can be estimated via Equation 14. Values above this should be corrected if needed at a rate of -12dB per octave (assuming a perfectly elastic collision), though estimates up to the various $T_c$ limits are usually sufficient to provide a good indication of potential effects.

$$f_{cut-off} = \frac{1.5}{T_c} \qquad 14$$

*Figure 6: Effects of contact time on maximum force*

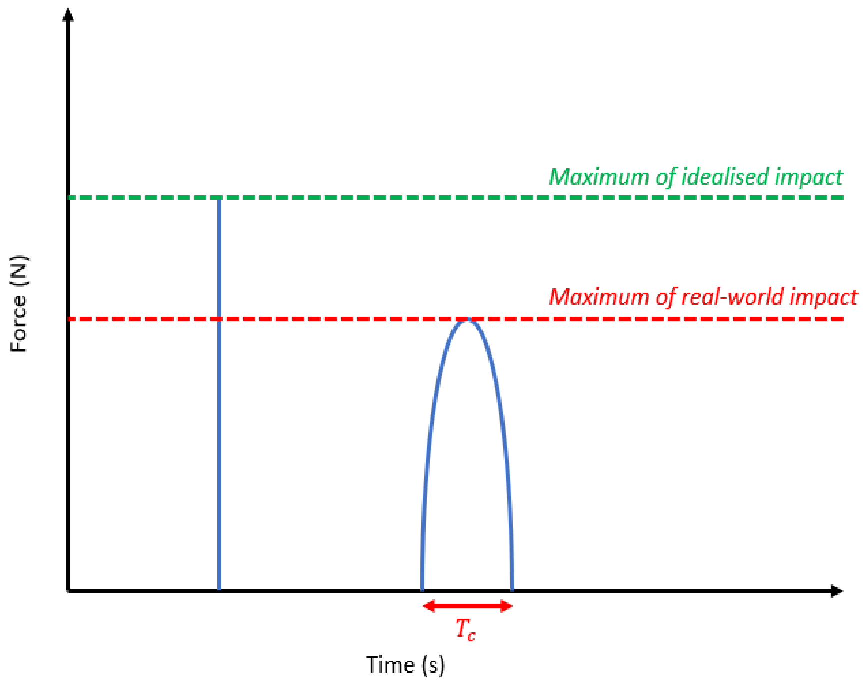
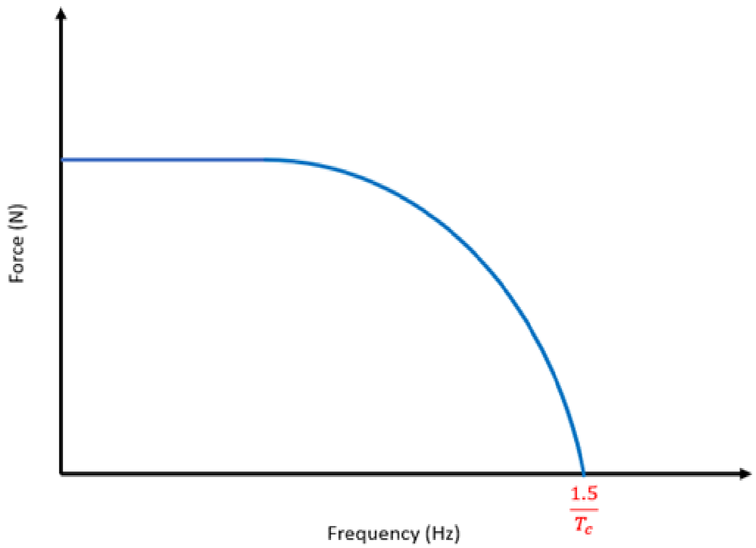



*Figure 7: Cut-off frequency in frequency domain*




## 4.5. Uncertainty

As stated from the outset, the method presented here shall be considered an engineering method rather than one of precision. When considering the variation in both material and physical-testing parameters that exist, a degree of uncertainty has to be assumed and any assessments in accordance with the methodology herein shall present results as a range of values rather than a single absolute figure.

If comparison is made to an overall A-weighted value, then this method has been found to typically agree with measured values with a +/- 6dB tolerance in rooms directly below the source room where it can be reasonably agreed that assumed contact time during impact is representative. A spread of values greater than this, in the region of 10dB variance, could be expected if there are no measurements to validate contact time estimations or the modal limitations of structures and receiving room are not accounted for. It is likely the greatest error will occur in the low-frequency region, particularly if the modal density is poor.

## 4.6. Prediction of Vibration.

The procedure presented in Section 4.3 can be used to estimate the average vibration level within a floor, if required. The power input and total loss factors can used to obtain the energy level in the floor/plate as

$$E_1 = \frac{W_{in}}{\omega \eta_1} \qquad (15)$$

Since energy is the product of mass and the square of velocity, it is possible to estimate the time and space average mean-square velocity as

$$\langle v^2 \rangle = \frac{E_1}{m} \qquad (16)$$

And in decibels as

$$L_v = 20\left(\frac{v}{10^{-9}}\right) \qquad (17)$$

Where $m$ is the mass of the floor in kg and $E_1$ is the energy level of the plate/floor expressed in decibels re $10^{-12}$ J. Where estimates of $L_{max}$ or other such time metrics are required, then the contact time corrections described in Step 4 of the previous section shall be applied.

## 4.7. Estimating vertical transmission through structures

It is common that gym facilities are located below a sensitive receiver as opposed to directly above. This introduces issues for quick computation as transmission routes become more complicated, mainly on account of having a greater dependence on structural form and the associated dynamics the structures exhibit during excitation.

There are a number of desktop assessment routes that may be considered, a non-exhaustive list is provided below:

- Use of EN 12354 framework with structure borne power characterised in accordance with Section 4.3 or another appropriate format (see Hopkins/Cremer for example). This is a form of SEA analysis for transmission paths of interest.
- A fully developed SEA model of the structure.
- Finite Element (FE) or Finite Difference Time Domain (FDTD) forms of simulation.
- Empirical assessment.

There are various advantages and disadvantages that the acoustician must be mindful of. Putting aside the uncertainty embedded within the action of falling masses, there are further issues encountered once predictions are propagated at distance throughout structures, rather than centred at proximity to points of impact.

For example, a reliance on the infinite nature of plates and the assumption that only bending wave motion takes place may underestimate the overall response when connecting many structural elements and would therefore fail to capture the complete nature of vibration transmission. These issues are more likely to occur in methods such where a spreadsheet-based approach is favoured.

Numerical assessments, such as FE or FDTD procedures are computationally expensive, often require specialist training and are likely to be cost prohibitive for everyday feasibility assessments. In addition, such models require a fixed set of material property parameters when in reality may be within a realistic range of values – resulting in a random distribution that would be hard to capture without repeated simulation (such as Monte Carlo methods) or other such forms of analysis where distributions/variance can be established.

Empirical methods are likely to be a favoured choice for most practicing acousticians however care must be taken to ensure that any corrections or relationship factors used in predictions are fit for purpose and stated with well-reasoned bands of uncertainty.

From experience, the reduction of vibration (and associated re-radiated noise) from floors directly above gym spaces can vary significantly and losses as low as 2dB and as high as 15dB are not uncommon. Lower losses values exist in smaller environments on account of source room vibration levels being largely constant. In such cases, the floor-to-floor reduction in vibration level is more in line with values typically assumed in assessments of groundborne vibration from rail – namely in the region of 1-3dB per floor.

Once third-octave band corrections are made to the vibration velocity level ($L_v$), the following equation can be used to estimate the re-radiated noise component from floors.

$$L_p = L_V + 10(\sigma) - 10(H) - 20 + 10(T_{60}) \qquad 18$$

Where $Lv$ is the vibration velocity level in dB re$10^{-9}$ m/s, H is the room height (metres) and $T_{60}$is the receiving room reverberation time (seconds).

## 4.8. Estimating the effects of mitigation.

There are a number of approaches for dealing with estimating isolation performance. An SEA-based framework, as presented in Section 4.3, can be modified to accommodate the presence of a floating floor however there is a risk that adding idealised isolation systems into an already idealised assessment framework may overestimate the reductions that are achievable in practise. This approach is cautioned against for this reason.

Further, the presence of heavy impacts means that one may be required to introduce additional subsystems and coupling assumptions. Though this would be a necessary step for a full and high accuracy means of prediction, is considered beyond the technical scope and intent of this document.

The reality is that the reduction in noise and vibration offered by specialist supplier systems will vary and prediction via mock-up or more advanced means such as those using reception plate methodologies may be more beneficial. Such methods are a better means of minimising uncertainty, since high performing mitigation constructions, such as floating floors, often comprise several interlayers making prediction accuracy a challenge.

It is acknowledged that the above may be a difficult approach to take in practise or will need to be undertaken at an early stage in a project, where scoping-level assessments are required.

A practical approach, (and one often used by suppliers and acousticians alike), is to estimate the improvement gained from an isolation system acting as a single degree of freedom (SDOF). This approach does have value but is limited in capturing accurate in-situ effects, since such methods discount dynamics of supporting structure and it is difficult to provide a catch-all solution for variable weights due to non-linearity effects in elastomer/rubber-based isolating materials. A compromise is often made by limiting the calculated reductions to reflect the amplification due to structural dynamics, though there is no consensus on what upper limit best reflects real-world conditions.

The following guidance outlines some typical performance values that can be expected from a variety of systems often encountered in gym facilities. It is assumed that the cap in performance is produced by a SDOF calculation and based on the dynamic stiffness of isolators, pads, springs or other mounts forming the mitigation element.

It should be stated the values in Table 3 are guidance values only and should not be used for suitability of selections without input from a suitably qualified acoustician and a specialist supplier to provide detailed information on the feasibility of systems proposed or considered against the mitigation performance targets. The presence of resilient elements will alter the contact time of impact-events and therefore spectral content, so it is essential that the values be treated as guideline values only, rather than precise indicators of in-situ performance.

*Table 3: Typical performance estimates for various isolation systems*

| **Isolation type** | **Typical system thickness mm** | **Typical capped-maximum[1] reduction in impact noise/vibration per third-octave band dB[2]** |
|---|---|---|
| Pad/Matting (multiple layers) | 100-150 | 10-20 |
| Pad/Matting with solid elements | 150-190 | 30-35 |
| Floating timber floors/sport floors | 80-100 | 10-15 |
| Floating concrete floors with matting to upper surface | 200-350 | 30-40 |

[1] *Values correspond to stated thickness ranges.*

[2] *Values assume a concrete structural floor. Very thin or lightweight structures would be expected to have lower values than presented.*

# 5. SPECIFICATION OF MITIGATION

The primary purpose of specification is to ensure that the client is provided with the correct and optimal treatment, an understanding of why they are recommended and the practical ramifications of them. Not all treatments can be accommodated structurally, there will be a loss of height, which can affect thresholds and ability to lift weights above head height plus a financial implication which may affect the gym operation and business model. It is recommended that the scope of works for the acoustician extends to a review of the system proposed by the supplier(s).

Site testing of mock-ups is the preferred approach for determining the optimum floor configuration, although as discuss in section 4.7 there are limitations that need to be taken into account. This approach should be made clear to the contractor/client to ensure that they understand that every floor is different. In some cases, floor treatment can be over specified and needless additional costs to the client could result. There is very significant variance in materials, design and floor construction methods so all should be detailed. For covering layers, the following apply. Some aspects may require support and assurance from the supplier:

1. Material of each layer required.
2. Thickness of each layer required.
3. A construction method that will not cause issues in the future, for example layers 'rucking' up or separating due to incorrect adhesion.
4. A heavy wear layer suitable for adult gym use to prevent the material breaking down over time.
5. Consideration on stability under foot, overly soft constructions pose a health and safety risk and may require subjective assessment by the client.
6. Layers and construction should be appropriate for equipment loadings. (Heavy gym equipment can cause damage or cause layers to separate).

If a floating floor is required under covering layers, the following would be helpful. Some aspects may require support and assurance from the supplier:

1. Where a specific floor system is not provided the required natural frequency of the isolating elements or force reduction performance, to be achieved under dead load of the floor and equipment, may be helpful.
2. All isolating elements to be individually adjustable or shimmed to ensure uniform load and performance of floating floor across the floor plate for floor level and assured response. Alternatively proof of uniform load across the floor plate would be equally acceptable.
3. The maximum creep should be limited to 25% deflection or other suitable standard.
4. If elastomeric, the dynamic stiffness can be specified by either the acoustician or the supplier. Typically, this would be a maximum of 1.4 and should not change over the design life of the project.

5. If spring, they should sit in an elastomeric cup capable of eliminating spring ring frequencies.
6. Specify the minimum air gap required and if necessary, venting measures.
7. Specify the minimum floating floor thickness and mass.
8. The floor design should provide consistent response irrespective of floor loading due to equipment or other features.

The above headline factors can be supported by the following details. The intent of the below is to assure longevity and to ensure the supplier is involved in the process, up to and including project completion.

## 5.1. Problematic Gym Equipment

Where problematic gym equipment is to be used, treatment can be used to aid isolation of certain machines rather than applying full floor systems, examples are:

1. Leg press – often a heavier weight is 'pushed' when using a leg press compared to other resistant machines and this resultant impact can be reduced by including specialist impact washers to the base of the weight stack and guide rails reducing the potential impact into the slab. This is to be used in conjunction with a specialist floor system and is not intended to replace the isolating floor. These impact washers can be used on all equipment with weight stacks and are positioned at the base of the weight stack guide rails.
2. Olympic lifting platforms – these can be isolated locally, typically on a suitable isolating floor system with suitable mass and strength to deal with point load impacts, the project acoustic and structural consultant should also have input on the suitability.

## 5.2. Other Factors

If it is found that there is no specialist floor requirement, a simple impact layer is recommended beneath the gym floor finish, this provides slab or subfloor protection so that when flooring might be replaced, it can be undertaken on an undamaged subfloor.

## 5.3. Scope

The aim is to isolate the gym activity from the building structure by means of a floating floor and/or covering layer(s). The result shall be a flooring system which isolates gym activities to a degree as determined by physical testing/prediction carried out by the project acoustician.

As per the following paragraphs, the flooring system supplier should provide independent evidence of final system performance in line with testing carried out, construction guidance, products of demonstrable quality and support to ensure correct installation.

## 5.4. Specification

The supplier should have a responsibility to work with the project acoustician and the client team to demonstrate (via calculation or empirical evidence as applicable) that the proposed floor system:

1. Will provide isolation in line with physical testing carried out on site. It is advised that the supplier supports the testing process;
2. Will be capable of supporting all intended gym equipment without detriment;
3. Will not exceed the structural capacity of the existing structure. The supplier shall further provide any loading information required by the client team. The supplier should work with the team and make recommendations on how limitations can be overcome;
4. Will allow for safe access by users, including those with disabilities;
5. Will allow for system penetrations for piping, drainage ducts etc. considering system moment while ensuring isolation is not compromised;
6. Will be appropriately restrained if within a seismic or blast zone;
7. Will be appropriately interfaced with any surrounding walls.

## 5.5. Product and submission quality

In order to demonstrate that the overall proposal and all products supplied are of suitable quality, the supplier should provide as a minimum:

1. Detailed product drawings and load/deflection curves of all isolating elements;
2. AASHTO (see table 1), BS EN 1337-3-:2005, or agreed equivalent on properties related to product longevity from an accredited independent laboratory for all elastomeric compounds used, in order to ensure that isolators will not stiffen or crush for a suitable period; 50 years is appropriate for semi-permanent floating floor isolators;
3. For concrete floors, housings and interfaces should be circular in plan to reduce risk of cracking;
4. For elastomeric elements supporting a floating floor, independent laboratory testing demonstrating that dynamic stiffness does not exceed 1.4 (not relevant for all products);
5. All elastomeric elements capable of minimum 200% overload and spring capable of 150% overload to account for live loading;
6. A drawing or drawings showing:
    a. Dead, live and concentrated loads;
    b. Isolator sizes, locations and characteristics;
    c. All interface details requiring a soft/isolation joint;
    d. Seismic/blast elements as required and supporting calculations;
    e. Any penetrations and interface details;
    f. Outline construction detail.

*Table 4: AAHSTO / BS EN 1337-3:2005 Bridge Bearing Specifications for polyisoprene*

| **PHYSICAL PROPERTIES** | | | **TESTING FOR AGING** | | | | |
|---|---|---|---|---|---|---|---|
| | | | **HEAT RESISTANCE (70h/70°C)** | | | **OZONE** | **COMPRESSION SET** |
| Tests: ASTM D-2240 and D-412 | | | ASTM D-573 | | | ASTM D-1149 | ASTM D-395 |
| Hardness (Shore A Durometer) | Tensile Strength (min) | Elongation at Break (min) | Hardness Change (max) | Tensile Strength Change (max) | Elongation at Break Change (max) | 25 pphm in air by volume 20% strain 400C | 22 hours 700 C (max creep) |
| 50 +/- 5<br>60 +/- 5<br>70 +/- 5 | 15.5 MPa<br>15.5 MPa<br>15.5 MPa | 450%<br>400%<br>300% | 10%<br>10%<br>10% | -25%<br>-25%<br>-25% | -25%<br>-25%<br>-25% | No Cracks<br>No Cracks<br>No Cracks | 25%<br>25%<br>25% |

## 5.6. Construction support

The supplier and/or installed should be responsible for providing guidance to the client on the planning and correct installation of the floor system:

1. Assessment of suitability of site for proposed works, for example logistics;
2. Provide a full construction drawing supported by applicable PI cover;
3. Be capable of providing support as required by the client, to include:
   a. Risk assessment and method statements (RAMS) and other advice on health and safety;
   b. Supervision of installation and/or full installation service with appropriately qualified and experienced staff.

# TERMINOLOGY

1) **Noise**: Generally described as unwanted sound.

2) **Decibel (dB)**: The range of audible sound pressures is approximately 0.00002 Pa to 200 Pa. Using decibel notation presents this range in a more manageable form, 0 dB to 140 dB.

   Sound Pressure Level (dB) = $20\log(p(t)/P_o)$

   Where $P_o = 2 \times 10^{-5}$ Pa

3) **Frequency (Hz)**: The number of cycles per second, this is subjectively perceived as pitch.

4) **Frequency Spectrum**: Analysis of the relative contributions of different frequencies that make up a noise.

5) **Octave Bandwidth**: A range of frequencies defined by an upper limit which is twice the lower limit. Octave bandwidths are identified by their centre frequency.

6) **"A" Weighting (dB(A))**: The human ear does not respond uniformly to different frequencies. "A" weighting is commonly used to simulate the frequency response of the ear.

7) **Tonal**: Having a discrete, or isolated frequency component.

8) **Broadband**: Having approximately equal contributions from all frequencies.

9) **$L_{eq}$/$L_{Aeq}$(T)**: The equivalent continuous sound level. It is that steady sound level which would produce the same energy over a given time period T as a specified time varying sound.

10) **$L_{max}$/$L_{Amax}$**: The maximum sound pressure level that occurred during a given measurement period; can be given as a linear level ($L_{max}$) or A-Weighted ($L_{Amax}$). This can also be measured and conveyed for both the 'Fast' response ($L_{Fmax}$/$L_{AFmax}$), or the 'Slow' response ($L_{Smax}$/$L_{ASmax}$).

11) **$L_{A90,T}$**: The A-weighted sound pressure level of the residual noise in decibels exceeded for 90% of a given time interval, T. The background noise level is typically quoted to the nearest whole number of decibels

12) **SEL**: The Single Event Level. It is that steady sound level which if maintained for 1 second would have contained the same energy as the specified time varying sound. It is widely used in the measurement of discrete or isolated noise events.

13) **Airborne Sound Transfer**: Direct airborne sound or noise that travels across and through a structure (e.g. wall or floor) or through a number of structures and rooms.

14) **Structure Borne Sound Transfer**: Sound or noise energy that enters structural elements (e.g. walls, floors, columns) and causes these elements to vibrate and transfer energy across the structure or building itself, this is then reradiated by the

receiving structures as noise; similar to a tuning fork or speaker that vibrates and emits a sound when excited.

15) **Flanking Noise or Flanking Paths**: The noise that does not take a direct path across a partition or main structure and 'flanks' around the weakest elements of the partition; these typically occur at the junctions/perimeters of a wall or floor partition.

16) **Vibration**: Vibration is a mechanical phenomenon in materials (other than air) whereby energy causes oscillations to occur about an equilibrium point. The oscillations may be periodic, random or impulsive.

17) **Permitted developments**: One can perform certain types of work or redevelopment without needing to apply for planning permission. These are called "permitted development rights". They derive from a general planning permission granted not by the local authority but by Parliament.

18) **Acoustic Commissioning**: At the end of a gym related project, when all construction, remedial, mitigation and fit-out works have been completed, an SQA returns to site and undertakes airborne and/or impact measurements into the noise sensitive receiver to establish the final acoustic results and whether the relevant criteria have been achieved.

19) **Planning Condition**: The National Planning Policy Framework (NPPF) defines a planning condition as, 'a condition imposed on a grant of planning permission (in accordance with the Town and Country Planning Act 1990) or a condition included in a Local Development Order or Neighbourhood Development Order'. Rather than refusing a planning application, a local authority might grant permission, but with conditions.

20) **Noise Management Plan**: Refer to Appendix A2 for the full description

21) **Substrate**: In the context of this document, this refers to underlying existing layers, such as a concrete slab upon which additional materials would be added.

22) **Deflection**: *is the degree to which a structural element is displaced under a load (due to its deformation).*

23) **Cavity Damping Effects**: The ability for a cavity to dampen the noise or vibration energy as these pass through the cavity (void).

24) **Non-homogeneous floor treatment**: Not a just one layer of floor treatment, but several layers of varying materials. A single layer of 70 mm rubber for example, would be considered a homogeneous floor treatment

25) **Reverberation Time (RT)**: The reverberation time (or echo) is measured as the time taken for the energy in an initially-steady reverberant sound field to decay by a given amount (usually 20 dB or 30 dB). Reverberation can provide a subjective sense of scale to a space. A space with a short reverberation time is often described to be acoustically 'dead' (i.e. a recording studio with RT 0.3 seconds) and can feel enclosed. A 'live' acoustic environment with a long reverberation time (i.e. assembly hall with RT 1.5 seconds) will provide a sense of scale/space.

26) **Investigative Acoustic Testing**: When responding to a noise complaint, this is typically investigated. One of the means to investigate the issue of the complaint is to undertake in-situ various acoustic tests to investigate (or simply rule-out) the cause and effects.

27) **RMS Acceleration**: Acceleration measured as the **R**oot **M**ean **S**quared, essentially the average acceleration of the vibration wave (were this wave a pure sinusoidal wave).

28) **VDV**: **V**ibration **D**ose **V**alue metrics. The assessment procedure consists in calculating/measuring cumulative vibration levels over 16hr daytime and 8hr night-time periods, which are then compared against a range of levels associated with different predicted levels of adverse comments. eVDV is the estimated Vibration Dose Value, which is a calculated value.

29) **BS 6472: 2008**: 'Guide to evaluation of human exposure to vibration in buildings - Part 1: Vibration sources other than blasting' - Vibration exposure levels for residents and associated likelihood of adverse effects

30) **Synchronised Repetitive Excitation**: A repeated excitation that is created by more than one source (person) but with the excitation being coordinated/simultaneously.

31) **Receive Room**: The room that is receiving the noise or vibration. When measuring in a room that is not the source of the noise or vibration, this is the receive room.

32) **Dynamic Stiffness**: As opposed to static stiffness which is the ratio between a static object and how much deflection is created by that static object, Dynamic Stiffness is equivalent but applies to a dynamic (moving) force and the ratio of the moving object versus the dynamic deflection that this is imparting on a material or structure.

33) **Impedance**: The resistance of a spring or material to deflection.

34) **Non-linearity effects**: *A situation where there is not a direct linear relationship between an independent variable and a dependent variable.*

# ABBREVIATIONS

AASHTO – American Association of State Highway and Transportation Officials

AGC – Automatic Gain Control

AN – Airborne Noise

ANC – Association of Noise Consultants

AOC – Agent of Change

BPM – Best Practicable Means

CIEH – Chartered Institute of Environmental Health

EHP – Environmental Health Practitioner

EPA – Environmental Protection Act

eVDV – Estimated Vibration Dose Value

FDTD – Finite Element Time Domain

FE – Finite Element

GAG – Gym Acoustic Guidance

HIR – High Impact Response

HSE – Health and Safety Executive

HTM – Health Technical Memorandum

IEMA – Institute of Environmental Management and Assessment

IOA – Institute of Acoustics

LF – Low Frequency

LFNR – Low Frequency Noise Rating

LOAEL – Lowest Observed Adverse Effect Level

LPA – Local Planning Authorities

NMP – Noise Management Plan

NOEL – No Observed Effect Level

NPPF – National Planning Policy Framework

NPPG – National Planning Practice Guidance

NPSE – Noise Policy Statement England

NR – Noise Rating

PCT – Pre-Completion Testing

PI – Professional Indemnity

PPE – Personal Protective Equipment

PPG – Planning Policy Guidance

ProPG – Professional Practice Guidance

RAMS – Risk Assessment and Method Statement

RFF – Rubber Floor Finish

RMS – Root Mean Square

RT – Reverberation Time

SCI – Steel Construction institute

SDOF – Single Degree of Freedom

SEA – Statistical Energy Analysis

SEL – Single Event Level

SLA – Service Level Agreement

SLM – Sound Level Meter

SOAEL – Significant Observed Adverse Effect Level

SQA – Suitably Qualified Acoustician

SRE – Synchronised Repetitive Excitation

TSEA – Transient Statistical Energy Analysis

UKAS – United Kingdom Accreditation Service

VC – Vibration Criterion

VDV – Vibration Dose Value

WCC – Westminster City Council

# APPENDICES

# A. ADVICE FOR DEVELOPERS & OPERATORS

## A.1. Advice for developers

When selecting the site it is important to consider the immediate surroundings of the building. If the proposed unit is surrounded by shops in a retail park it is likely to be easier to mitigate the noise and vibration from activities than if it is in a residential building or adjacent to one. However, as has been covered in this document, the construction type of the building is also important.

Acoustic testing should be carried out as soon as is practical after a site is selected as a possible gym. The acoustic testing will identify how suitable a site is for a gym, and what acoustic interventions are necessary to make suitable. This is important as some sites may have weaknesses that only testing will show, and in some cases the cost of the acoustic interventions will make the site unviable.

Developers should ensure that the acoustician appointed is suitably qualified to carry out such testing.

Testing to the methodology set out in the guidance document should be carried out by at least an acoustician who is a Member of the Institute of Acoustics, ideally with at least three years of relevant experience.

Airborne and impact sound insulation testing should be carried out by an acoustician who is a Member of the Institute of Acoustics with at least three years of relevant experience. It would be beneficial for the tester and their company should also be registered to undertake pre-completion acoustic testing with the Association of Noise Consultants or the United Kingdom Accreditation Service (UKAS). Where this is not the case supporting evidence that testing has been completed to ISO 16283:2014 Part 1 and 2020 Part 2 would be desirable.

## A.2. Noise Management Plan

The goal of the noise management plan is to inform staff of their study to minimise operational noise and reduce the risk of complaint from nearby receptors.

Examples of operational noise are listed below:

- Voices of customers.
- Voices of employees/instructors.
- Music.
- Sound effects between exercise sets (i.e. beeps).
- Re-racking of weights and other equipment.

A noise management plan should be site specific and cover all potential sources of noise. Customers should be told to place weights onto the floor rather than dropping them, and to re rack equipment carefully were the limitations of the design require this level of management control. Gym staff should assume an 'active' monitoring role to educate its customers of this need and reprimand repeating offenders.

## A.3. Complaint management

In the event of a complaint, it may assist to have a clear management protocol. One suggestion for this is set out below, with alternatives being tailored to the operator.

The management should listen to the complaint in full and consider what improvements could be made to mitigate any further disturbances, considering both immediate action and if necessary, a long-term strategy.

Complaints should be documented and kept on record, along with the response, immediate actions and long term actions in an incident book. This should be made readily available to an authorised officer of the local authority or police.

Procedure and reporting actions to include:

- Who is responsible for managing incoming complaints; The Directors & Branch Manager.
- How a complaint can be made; published email address and telephone number.
- How the complainant will be kept informed; with a polite direct response or face to face meeting request.
- Record keeping procedures; the operator will look to retain soft copies of any complaints received and their responses for a period of six years via encrypted cloud-based storage.
- Investigation/Resolution process – complaint specific, but a 14 day rule will be committed, that being we will look to seek advice and derive a long term fix within a 14 day period.

Management should inform nearby receptors of upcoming events and gain feedback, in order to build relationships and trust.

## A.4. Staff service level agreement

It is often helpful to include a Service Level Agreement (SLA) to set out clearly what is expected to assist the management of noise. One example of this, for staff, is included below.

A staff service level agreement may be included in the noise management plan for all staff to be familiar with and sign, indicating that they have received training on the noise management plan and that they will ensure that the premises is operated within its guidelines to the best of their ability. The noise management plan should be accessible so that staff can familiarise themselves with it, or refresh their memory.

## A.5. Timeline

The following timeline works as a guide to advise developers and operators when certain actions should be completed.

*Table A1: Timeline*

| | |
|---|---|
| **Feasibility (Optional):** | When first looking at a site it is recommended that a suitably qualified acoustician is appointed to inspect the site and determine, roughly, what sound insulation may be needed which may assist with budget estimates or rule out sites. |
| **Testing:** | Testing should be conducted by a suitably qualified acoustician. It should be undertaken from the proposed site to surrounding spaces to determine the level of mitigation required. The acoustic consultant assisted by manufacturer(s) should recommend suitable products that will reduce the noise impact to a level agreeable to the building owner and local authority. |
| **Contracts** | |
| **Construction** | |
| **Pre-Completion Testing (Optional):** | Optional: Pre-completion testing should be conducted by a suitably qualified acoustician. Some building owners or local authorities will want the testing repeated to confirm that the sound insulation measures have worked as predicted. |
| **Opening** | |

# B. CONDITION WORDING

## B.1. Planning Conditions

The Town and Country Planning Act 1990 is the primary legislation which provides Local Planning Authorities (LPA's) with powers to impose planning consent conditions. The principal powers are contained in sections 70, 72, 73 and 73A and Schedule 5 of the Act. Sections 91 and 92 deal with the imposition of time limited conditions. The Secretary of State or appointed officers may also impose conditions under section 77 and 79 of the Act.

National Planning Policy Framework 2012 (NPPF) -The NPPF must be taken into account in the preparation of local and neighbourhood plans, and is a material consideration in planning decisions. Paragraph 54 of the National Planning Policy Framework states "Local Planning Authorities should consider whether otherwise unacceptable development could be made acceptable through the use of conditions. Paragraph 56 of the National Planning Policy Framework states:

"Planning conditions should only be imposed where they are:

- necessary;
- relevant to planning and;
- to the development to be permitted;
- enforceable;
- precise and;
- reasonable in all other respects."

National Planning Practice Guidance 2014 -The NPPG was published as an online resource on 6 March 2014. The NPPG provides further details of the implementation of the provisions presented in NPPF. Regarding conditions its states in paragraph 4;

Whether it is appropriate for the Local Planning Authority to impose a condition on a grant of planning permission will depend on the specifics of the case. Conditions should help to deliver development plan policy and accord with the requirements of the National Planning Policy Framework, including satisfying the six tests for conditions.

Further guidance is provided on the use of conditions in paragraphs 5 to 34 of the NPPG.

## B.2. Planning Obligations

Planning obligations assist in mitigating the impact of unacceptable development to make it acceptable in planning terms. Planning obligations may only constitute a reason for granting planning permission if they meet the tests that they are necessary to make the development acceptable in planning terms, directly related to the development, and fairly and reasonably related in scale and kind. These tests are set out as statutory tests in the Community Infrastructure Levy Regulations 2010 and as policy tests in the National Planning Policy Framework;

A planning obligation may only constitute a reason for granting planning permission for the development if the obligation is:

a) necessary to make the development acceptable in planning terms;.
b) directly related to the development; and.
c) fairly and reasonably related in scale and kind to the development

## B.3. Outline applications

Details submitted as part of an outline application must be treated by the LPA as forming part of the development and conditions cannot be used to reserve these details for subsequent approval unless the applicant has made it clear that the details were for illustrative purposes only.

Therefore, it is recommended that LPAs should not grant outline planning permission for new noise/emission sensitive or noise/emission generating developments in circumstances where there is a potential risk of unacceptable significant adverse effects arising from noise or other emissions, without first having received and approved an acceptable level of detail.

## B.4. Circumstances Where Planning Conditions Should Not Be Used

Conditions requiring compliance with other regulatory requirements (e.g. Building Regulations, Environmental Protection Act): Conditions requiring compliance with other regulatory regimes will not meet the test of necessity and may not be relevant to planning.

## B.5. A Temporary Period

Under section 72 of the Town and Country Planning Act 1990 the local planning authority may grant planning permission for a specified temporary period only. A condition limiting use to a temporary period only where the proposed development complies with the development plan, or where material considerations indicate otherwise that planning permission should be granted, will rarely pass the test of necessity.

Circumstances where a temporary permission may be appropriate include where a trial run is needed in order to assess the effect of the development on the area or where it is expected that the planning circumstances will change in a particular way at the end of that period.

## B.6. Third Party Conditions

It is not appropriate to require in a condition that a development/requirement should be carried out to the satisfaction of a third party as this decision rests with the local planning authority.

## B.7. Conditions Precedent

Care should be taken when considering using conditions that prevent any development authorised by the planning permission from beginning until the condition has been complied with. This includes conditions stating that 'no development shall take place until…' or 'prior to any works starting on site…'

Such conditions should only be used where the local planning authority is satisfied that the requirements of the condition (including the timing of compliance) are so fundamental to the development permitted that it would have been otherwise necessary to refuse the whole permission. A condition precedent that does not meet the legal and policy tests may be found to be unlawful by the courts and therefore cannot be enforced by the local planning authority if it is breached.

Examples;

- Development / construction shall not begin until
- Prior to occupation of the development / units hereby approved
- Prior to a material start
- Prior to the commencement of the development

## B.9. Example Planning Conditions

### London Borough of Richmond - Planning Condition Approach

A high level of airborne and impact sound insulation, often only achievable by complex design methods that structurally isolate the noise generating and noise sensitive premises, will be required in situations such as where music and dancing or gym or health and fitness activities adjoin a residential use. Each case will take into account the specific circumstances of the proposed development, and the example limits in the SPD Table 6 may not be appropriate for assessing performance as they do take account of the full extent of low frequency noise transmission. The following type of information would be considered in such applications;

- Establish the noise and vibration transfer paths from source to noise sensitive receiver
- Establish the potential airborne and impact noise and vibration transfer magnitudes from source to noise sensitive receiver.
- Design a sound isolation and insulation treatment such as a floating floor and wall treatment which mitigates and minimises adverse noise and vibration effects and is appropriate for the types of activity being undertake within the proposed development.
- Undertake post completion testing to demonstrate how noise and vibration has been controlled adequately.

- It is recommended that early discussions are undertaken with the Environmental Health Department to discuss the specific application

**Example - Noise Control Scheme Condition**

The noise control scheme (including sound insulation and isolation measures) installed/implemented in order to limit both airborne noise and structure borne noise, from the use of the health and fitness studio, shall ensure that the airborne and impact noise limit levels detailed in Table 1 below are achieved.

Full details of the noise control scheme shall be included within the Noise Management Plan and submitted to and approved by the LPA prior to the first use of the health and fitness studio.

The works and scheme shall thereafter be retained in accordance with the approved details. No alteration to the scheme which undermines the sound insulation or isolation integrity of the areas it applies to, shall be undertaken without the grant of further specific consent of the local planning authority.

*Table B1: Airborne and Impact Noise Limits (*using upper valued from Table 2)*

| **Operational Hours** | **Limit Level** |
|---|---|
| X to Y | **Airborne Noise**<br>Health and fitness activity noise shall be no greater than NR 25 $L_{eq, 5minutes}$*, as measured or predicted in any structurally adjoining habitable areas of residential properties located above or adjoining the health and fitness studio. |
| | **Impact Noise**<br>Health and fitness activity noise shall be no greater than NR 20 $L_{max, 5minutes}$*, as measured or predicted in any structurally adjoining habitable areas of residential properties located above or adjoining the health and fitness studio. |

REASON:

To protect the amenity and quality of life of occupiers of nearby properties from noise or vibration disturbance

**Example - Amplified Sound System Condition**

1. A dedicated in-house sound system shall be used exclusively for the amplification of music and speech which is produced in association with activities undertaken within the health and fitness studio.

2. All speakers which operate through the sound system shall be mounted on resilient mountings or hangers to limit the transfer of structure borne noise. The specification of the mountings shall be submitted to and approved by the LPA.
3. An Electronic Sound Level Attenuation System otherwise known as an Automatic Gain Control (AGC) device shall be fitted before the amplifier in the signal chain with the thresholds of the limiter set on both the Left and Right stereo channels. The sound attenuation device shall be set by a suitably qualified acoustician/sound engineer and secured so that it cannot be overridden by persons other than the appointed sound system engineers/acoustic consultant. The sound attenuation device shall not be altered without prior agreement with the LPA or Environmental Health Service. The specification of the Sound Level Attenuation System shall be submitted to and approved by the LPA.
4. Before the first use of the health and fitness studio an acoustic assessment shall be undertaken by a suitably qualified acoustic consultant and a report be submitted to and agreed by the LPA which demonstrates how the sound attenuation device has been set in order to achieve the requirements of the entertainment noise control criteria below.

*Table B2: Amplified Sound Limit (*using upper valued from Table 2)*

| Operational Hours | Limit Level |
|---|---|
| X to Y | Any amplified music and/or speech sound shall result in a sound level no greater than NR 25 $L_{eq,5minutes}$*, as measured or predicted in any structurally adjoining habitable areas of residential properties located above or adjoining the health and fitness studio. |

REASON:

To protect the amenity and quality of life of occupiers of nearby properties from noise or vibration disturbance.

**Example - Noise Management Plan Condition**

1. A Noise Management Plan (NMP) shall be submitted to and approved by the LPA prior to the first use of the health and fitness studio. The NMP shall include as a minimum, written details of the following information;
2. Organisational responsibility for noise control
3. Hours of operation of the health and fitness studio
4. Details of the planning conditions controlling noise
5. Details of all health and fitness activities that will be undertaken and activities such as free weights and Olympic lifting that will be restricted and/or prohibited.
6. Details of how the operational noise impact will be managed on a day-to-day basis, including the handling of weights to avoid high force impacts.

7. A plan showing the layout of the health and fitness studio area and proposed activity zones. The plan will include details of the noise insulation and isolation mitigation measures included within each activity zone, corresponding with the proposals in the Acoustics Report and approved drawings.
8. Specification details of all noise insulation and isolation materials installed within each activity area, corresponding with the proposals in the Acoustics Report reference.
9. Details of community liaison and complaints logging and investigation.
10. Details of review of NMP.

## Westminster City Council – Planning Condition Approach

The wording below is taken from typical planning conditions used for mixed use development in Westminster. Westminster's Draft Noise Technical Guidance Note [due to be approved as part of the Council's City Plan 2019-2040] sets out noise limits in the nearest residential habitable space.

*Table B3: WCC mixed use noise planning condition typical wording*

| **Typical use** | **Noise Criteria** | **Noise Parameter** |
|---|---|---|
| Music and entertainment (e.g. restaurants, clubs, pubs) | 10 dB below measured/assessed background in adjoining residential habitable space. | $L_{eq}$ & $L_{Fmax}$ in 63 Hz and 125 Hz octave bands |
| | Fixed criteria[1] | NR30 (day), NR25 (night) and NR40 ($L_{Fmax}$) |
| Gym facilities & other similar uses | 10 dB below measured/assessed background in adjoining residential habitable spaces | $L_{eq}$ & $L_{Fmax}$ in 63 Hz and 125 Hz octave bands |
| | Fixed criteria[1] | NR15 (Day & Night) $L_{eq}$<br>NR20 $L_{Fmax}$ |

[1] These criteria will be applied to development no matter the background/assessed

**Extract from WCC's Draft Noise Technical Guidance Note**

**Planning Conditions (Westminster City Council)**

1. Noise generated by the proposed new development (including noise from general operations, gym equipment, new plant and equipment, amplified sound, music etc.) in terms of $L_{Aeq,\ 5mins}$ should be demonstrated to be 10 dB below the existing background noise level measured in terms of $L_{A90,\ 5mins}$ inside the proposed residential dwellings. The background noise level used in the assessment should be representative of the most sensitive times (quietest) at which the new development is in operation (and generating noise).
2. Maximum noise levels generated by the proposed new development in terms of $L_{eq}$ / $L_{Fmax}$ should be demonstrated not to exceed the NR 15 / NR 20 curve respectively inside the existing residential dwellings. This includes noise from all sources (including amplified sound, music, impact noise from gym activities, activities in the retail unit). This is based on the assumption that existing background noise levels in the properties during the most sensitive periods are approximately NR 25 (approximately equivalent to 30 dB $L_{Aeq}$).
3. For music noise, the received music noise level in the residential habitable spaces should be demonstrated to be 10 dB below the existing ambient and maximum noise levels in the residential habitable spaces when music is not playing, at the quietest time of day and night, measured over a period of 5 minutes and in the indices of $L_{eq}$ and $L_{Fmax}$ in the octave bands 63 Hz and 125 Hz; The overall music noise level in terms of $L_{Aeq,5mins}$ should be at least 10 dB below the existing background noise level in terms of dB $L_{A90,5mins}$.
4. A Sound Limiter shall be installed and set by a competent acoustic engineer so that it maintains compliance with the above criteria. All amplification equipment within the development including music generating equipment and fitness instructor's announcement equipment shall be routed and controlled through the sound limiter. The operational panel of the noise limiter shall be secured by key or password so that only persons with management responsibility have access. No additional sound generating equipment shall be used on the premises without being routed through the sound limiter device.
5. You must apply to us for approval of an operational management plan for the gymnasium to show how you will actively manage the premises to comply with Conditions 1, 2, 3 and 4. You must not start the gym use until we have approved what you have sent us. You must then carry out the measures included in the management plan at all times that the gym is in use.
6. You must install all acoustic mitigation measures relating to internal noise transmission through the building structure as detailed in the submitted information Noise Mitigation Assumptions (version or date defined here), and maintain them in the form detailed for as long as the gym is in operation.
7. The gymnasium use allowed by this permission must not begin until you have carried out and sent us a post-commissioning noise survey and we have approved the details of the survey in writing.

**Informative (Westminster City Council)**

1. It is possible that existing background, ambient and maximum levels within the residential dwellings could be very low for measurement and assessment purposes. It is expected that the accuracy of results should be taken into consideration when dealing with the measurement of low noise levels. Standard Deviation of measurement is a recognised measure of accuracy of results and reasonable consideration should be given to Standard Deviation as well as the capabilities of the instrumentation used for the assessment. It is acknowledged that it is impossible to physically measure noise which is 10 dB below existing noise levels or measure NR criteria which is below existing NR levels. Therefore, it is anticipated that the assessment of Conditions 1,2 and 3 will include a comparison of 'on/off' conditions and seek to investigate the 'increase' in measured levels with the above points taken into consideration. For example; a level 10 dB below existing levels would increase existing levels by 0.4 dB.

2. The assessment of Conditions 1, 2 and 3 might also include a calculation approach where measurement is impracticable or a combination of measurement and calculation. Measurement assessment of Condition No's 1, 2 and 3 requires that residents allow the applicant access to carry out Acoustic testing to demonstrate compliance with conditions 1, 2 and 3 through measurement. If access is not made available, the applicant may deploy a calculation approach and base the criteria on reasonable assumptions of the existing acoustic conditions within the residential properties.

# C. LEGISLATIVE FRAMEWORK

The control of noise from new and existing commercial premises, including Fitness and Exercise Spaces fall under three discrete regulatory regimes:

- Building Control
- Development Control - Planning
- Statutory Nuisance - Environmental Health

The existing regulatory framework should provide the local authority with the necessary tools aimed at preventing, controlling and abating noise including noise from Fitness and exercise spaces. A brief description of each regulator regime is presented.

## C.1. Building Regulations 2010 - Approved Document E: Resistance to the passage of sound

The approved documents suite gives guidance for compliance with the Building Regulations for building work carried out in England and Wales and are approved by the Secretary of State. Approved Document E: Resistance to the passage of sound, primarily deals with domestic situations regarding airborne and impact noise protection and sets performance standards for purpose built dwelling houses and flats and dwelling houses and flats formed by material change of use.

With regard to non-domestic situations the Approved Document E: Section 0 (0.8) states:

*"The performance standards set out are in table 1a and 1b are appropriate for walls, floors and stairs that separate spaces used for normal domestic purposes. A higher standard of sound insulation may be required between spaces used for normal domestic purposes and communal or non-domestic purposes. In these situations the appropriate level of sound insulation will depend on the noise generated in the non- domestic space. Specialist advice may be needed to establish if a higher standard of sound insulation is required and if so, to determine the appropriate level".*

Therefore, there is very limited guidance provided through Building Regulations regarding the control of noise (impact and airborne) for non-domestic situations such as noise control from fitness and exercise spaces. What constitutes the specialist advice is therefore of critical importance.

## C.2. Development Control & Policy: National Planning Policy Framework (NPPF) 2019

National planning guidance is now contained within the National Planning Policy Framework (NPPF) 'the Framework' (March 2012, revised July 2019) and the Noise Policy Statement for England - NPSE (March 2010). Previously planning guidance on noise was contained within PPG24 (Planning Policy Guidance: Planning and Noise - PPG24, this guidance has now been withdrawn.) The NPPF was recently amended in July 2018 but keeps a similar emphasis regarding conserving and enhancing the natural environment.

Chapter 15 section 180 states:

*"Planning policies and decisions should also ensure that new development is appropriate for its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development. In doing so they should:*

*a) mitigate and reduce to a minimum potential adverse impact resulting from noise from new development – and avoid noise giving rise to significant adverse impacts on health and the quality of life;*
*b) identify and protect tranquil areas which have remained relatively undisturbed by noise and are prized for their recreational and amenity value for this reason; and*
*c) limit the impact of light pollution from artificial light on local amenity, intrinsically dark landscapes and nature conservation".*

Revised Planning Practice Guidance (NPPG) was released in March 2014 to support the NPPF. The Guidance stipulates that Local Planning Authorities' plan making and decision making should take account of the acoustic environment and in doing so consider:

a) Whether or not a significant adverse effect is occurring or likely to occur;
b) Whether or not an adverse effect is occurring or likely to occur; and
c) Whether or not a good standard of amenity can be achieved

Table 1 of that guidance is not reproduced here, but provides a noise hierarchy based on the likely average response.

## C.3. Agent of Change

The Agent of Change (AOC) principle has been formally included in the latest version of the National Planning Policy Framework 2018. Chapter 15 Section 182 states:

*"Planning policies and decisions should ensure that new development can be integrated effectively with existing businesses and community facilities (such as places of worship, pubs, and music venues and sports clubs). Existing businesses and facilities should not have unreasonable restrictions placed on them as a result of development permitted after they were established. Where the operation of an existing business or community facility could have a significant adverse effect on new development (including changes of use) in its vicinity, the applicant (or 'agent of change') should be required to provide suitable mitigation before the development has been completed".*

In practical terms this means that a party introducing a new use, be it noise generating or noise sensitive, should be responsible for managing the impact of the use. Where noise sensitive development is the agent of change (AOC), this may involve potential noise conflicts being dealt with by the housing developer and may include works to both the source and receiver premises, tenancy convents, financial exchanges or a multitude of arrangements to ensure that the noise generator and noise sensitive receiver can co-exist.

AOC does not currently have any statutory definition in law, other than in the NPPF as policy. However, housing developers and planning authorities should be aware of the principle and act upon it in circumstances where a new noise sensitive development is proposed close to existing Fitness and Exercise Spaces.

## C.4. Development Control & Policy: Town and Country Planning (General Permitted Development) (England) (Amendment) Order 2016

The 2016 amendment order (2016 no. 332) to 'The Town and Country Planning (General Permitted Development) (England) Order 2015' permits the change of use for commercial use premises to residential use without the need to seek full planning permission. Permitted developments are however subject to a process of prior approval by the Local Planning Authority. Seeking prior approval involves the consideration of a number of key factors.

"Development under Class O is permitted subject to the condition that, before beginning the development, the developer must apply to the local planning authority for a determination as to whether the prior approval of the authority will be required as to:

- Impacts of noise from commercial premises on the intended occupiers of the development

Updates to the use classes are happening regularly at the time of publication, and updates will be provided as they emerge. Updates can be found at the link provided in Appendix E.

## C.5. Development Control & Policy: Noise Policy Statement for England 2010

The NPPF affirms that National Policy Statements form part of the overall framework of national planning policy, and should be a material consideration in decisions on planning applications. The Noise Policy Statement for England (NPSE) came into force in 2010 and states:

*"Noise Policy Aims*

a) *Through the effective management and control of environmental, neighbour and neighbourhood nose within the context of Government policy on sustainable development:*
b) *avoid significant adverse impacts on health and quality of life;*
c) *mitigate and minimise adverse impacts on health and quality of life and;*
d) *where possible, contribute to the improvement of health and quality of life"*

The noise aims of the NPPF widely reflect those contained in the NPSE. The NPSE does however include some new concepts within the explanatory note in assessing noise impacts and uses established concepts from toxicology currently being applied to noise impacts including:

"NOEL – No Observed Effect Level. This is the level below which no effect can be detected. In simple terms, below this level there is no detectable effect on health and quality of life due to the noise.

LOAEL – Lowest Observed Adverse Effect Level. This is the level above which adverse effects on health and quality of life can be detected.

SOAEL – Significant Observed Adverse Effect Level. This is the level above which significant adverse effects on health and quality of life occur"

The NPSE confirms that it is not possible to have a single objective noise-based measure that defines SOAEL that is applicable to all sources of noise and in all situations. Consequently, what constitutes a LOAEL or SOAEL is likely to be different for different noise sources, for different receptors and at different times of the day, and needs to be defined for the given situation, with regard for context to become meaningful.

The National Planning Policy Guidance 2014 (NPPG) provides further guidance on noise exposure hierarchy.

## C.6. Statutory Nuisance - Environmental Protection Act 1990

Local Authorities have powers and duties to address issues arising from noise through the statutory nuisance provisions of the Environmental Protection Act 1990, Part III, Section 79-80 (EPA 90). Section 79(1) (g) of the EPA 90 defines a statutory noise nuisance as:

*"Noise emitted from a premises so as to be prejudicial to health or a nuisance."*

(Note: "noise" in this context also includes vibration)

Regulation using statutory nuisance provides a different level of protection in respect of problems that were not anticipated at the planning stage or which do not qualify as a public nuisance under the licensing system.

Nuisance is not defined within the act but retains its common law definition e.g. "An unlawful interference with a person's use or enjoyment of land, or of some right over, or in connection with it."

Under Section 79, pt. 1 of the EPA 90 Local Authority Environmental Health services have a duty to inspect their "districts" from time to time for statutory nuisances. Additionally, Local Authorities have a duty to take reasonable steps to investigate any complaint about alleged noise nuisance made by persons living in their district. Where they are satisfied (on the balance of probability) that a statutory nuisance in law exists, they have a duty to serve an abatement notice on the person(s) responsible for the nuisance. However, the requirements for establishing the nuisance branch of noise statutory nuisance are more than trivial; a substantial interference in personal comfort or amenity is required which must take into account factors such; as level of noise, time of day, frequency of occurrence, duration, utility, nature and character of the area.

Failure to comply with such a notice can result in further formal action being taken by the Local Authority. This includes prosecution of the recipient(s) of the abatement notice (to the criminal standard of proof) and/or seizure of noise-generating equipment (which can be forfeited on conviction for non-compliance with the abatement notice) with fines (currently unlimited); and where a public nuisance arises requests that licenses are reviewed can follow, based on local policy. This can result in changes of hours of operation, restraints on types of entertainment and permitted noise levels or even revocation of a licence.

## C.7. Statutory Nuisance - Best Practicable Means (BPM) Defence

Under certain circumstances, it is a ground for appealing an abatement notice and a defence against prosecution for non-compliance with such a notice to show that Best Practicable Means (BPM) were used to prevent, or counteract, the effects of statutory nuisance; and for the defence to succeed it is for to the defendant to prove that those means were adopted during the times the alleged offence(s) occurred.

The defence is available for industrial, trade or businesses under Section 80(8) of the EPA 90 states that the term "Best Practicable Means" is to be interpreted by reference to the following provisions:

*a) "Practicable" means reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to the financial implications;*
*b) the means to be employed include the design, installation, maintenance and manner and periods of operation of plant and machinery, and the design, construction and maintenance of buildings and structures;*
*c) the test is to apply only so far as compatible with any duty imposed by law;*
*d) the test is to apply only so far as compatible with safety and safe working conditions, and with the exigencies of any emergency or unforeseeable circumstances.*

Whether a BPM defence might succeed is dependent on the circumstances of each case; but BPM has featured in several judicial reviews and cases in the higher courts in relation to licensed premises.

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# F. HEALTH & SAFETY

## F.1. Lifting

Given that the proposed methodology will involve repeatedly lifting and dropping a weight, serious consideration needs to be given to manual handling requirements.

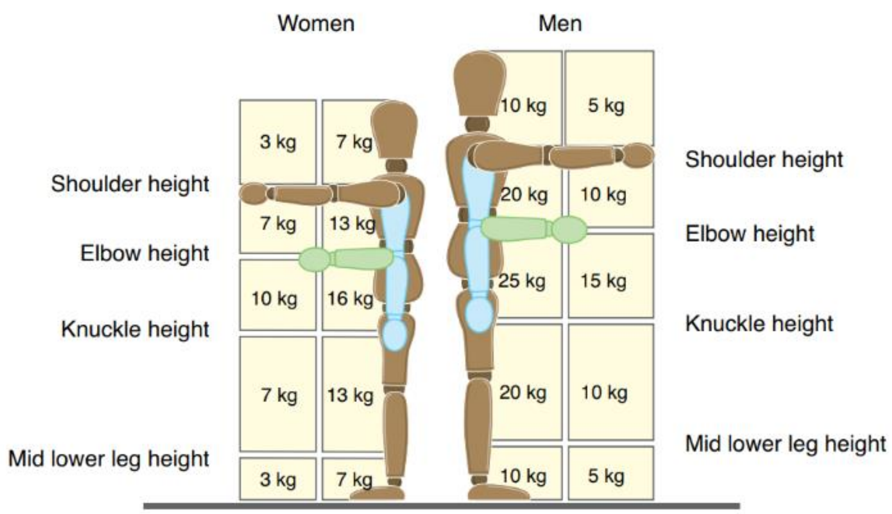
The Health and Safety Executive (HSE) provide the following guidance:

*The law does not identify a maximum weight limit. It places duties on employers to manage or control risk; measures to take to meet this duty will vary depending on the circumstances of the task. Things to be considered will include the individual carrying out the handling operation, e g strength, fitness, underlying medical conditions, the weight to be lifted and distance to be carried, the nature of the load or the postures to be adopted or the availability of equipment to facilitate the lift.*

*There is no universally safe maximum weight for any load, however, there are varying degrees of risk. The guidance on the Manual Handling Operations Regulations gives basic guideline figures for lifting and lowering which indicate when a more detailed risk assessment should be carried out.*

Notwithstanding, the following schematic provided by HSE is commonly consulted when considering suitable weight limits for manual handling for male/female operatives:

*Figure F1: Lifting and lowering risk limits for manual handling in the UK, reproduced from guidance*




Note: The above provides guidance based on average male/female body types but is not prescriptive for each individual.

It is necessary for a suitably high impulsive force generation for measurement (subject to drop height), whilst also enabling a consistent, safe and inclusive methodology across all genders.

A risk assessment should be undertaken for the lifting of weights by the employer of the acoustician conducting the tests, prior to undertaking such works. This should take into consideration the physical capability of each individual.

Consideration should also be given to the weight of flooring samples being carried to site/installed/removed during testing. Many of the gym rubber tile products available have a significant mass, and so suitable methods of lifting these should also be considered in line with HSE guidance and appropriate manual handling training.

## **F.2.** Suitable PPE

Due to the proposed methodology involving dropping weights, the operative should generally ensure at least the use of steel-toe-capped boots or alternative protective footwear is worn to avoid injury to feet in the event of the weight bouncing or rolling after impact or during transport to/from site.

# G. CASE STUDIES/DATA BENCHMARKS

## G.1. Case Studies & Data Benchmarks

INTRODUCTION: The following case studies describe how the gym floor treatments were selected through the testing of various acoustic and anti-vibration materials and sports floor coverings provided by specialist suppliers. There are several products available to test which are used in varying configurations which help to provide the correct floor build up specifically to each individual site that undergoes acoustic testing.

The current method of testing used which varies by practice, but in general, this includes the placement of various specialist resilient layers including a sports floor finish, whether this is a roll or tiled product. The same dumbbell or kettlebell is 'drop tested' on various configurations with readings then taken within the receiver room/s.

Typically, these drop tests would take place wherever the free weights area is to be positioned within the gym, or, if that is yet to be decided, then tests can be carried out in various positions including where the worst case might be, for example mid span of the structural floor.

Acoustic testing for gym floors is necessary when other occupants within the same or adjoining buildings may be affected from impact and airborne noise, for instance in a new mixed-use development or from change of use in an industrial unit which may also have offices for instance.

## G.2. Case Study 1: New gym in a commercial unit (change of use).

The aim of the testing is to assess the site's suitability for use as a new gym demise. It is proposed that the new gym demise will consist of fit-out of the entire ground floor unit and will include the construction of a new mezzanine floor area which will house the studio space. Testing was carried out in the area where free weights were to be used in practice. The potential noise sensitive receptors are:

Receptor A – Adjacent commercial unit currently occupied as shop floor area.

Receptor B – Adjacent commercial unit currently occupied by a showroom store, back of house staff room & kitchen area.

Measurements of noise resulting from the repeated dropping of a 30kg dumb bell have been undertaken on a range of materials from several different suppliers. Tests are aimed at reducing the impact related noise of such events within the sensitive receptors, such that they meet the criteria in Section 2 of this guidance. The results for each receptor are shown against the dropping of the same weight on the current bare floor finish to illustrate improvement, and against the typical ambient noise level to illustrate potential impact.

*Table G1: Typical receptor A shop floor area Operational Ambient Noise Data*

| **Frequency** | **63Hz** | **125Hz** | **250Hz** | **500Hz** | **1kHz** | **2kHz** | **4kHz** | **dB(A)** |
|---|---|---|---|---|---|---|---|---|
| Typical maximum ($L_{Fmax}$) noise | 68 | 61 | 57 | 51 | 48 | 47 | 43 | 55 |
| Typical ambient ($L_{eq}$) noise levels | 54 | 53 | 50 | 44 | 42 | 41 | 36 | 48 |

*Table G2: Typical receptor B back of house staff room & kitchen area Operational Ambient Noise Data*

| **Frequency** | **63Hz** | **125Hz** | **250Hz** | **500Hz** | **1kHz** | **2kHz** | **4kHz** | **dB(A)** |
|---|---|---|---|---|---|---|---|---|
| Typical maximum ($L_{Fmax}$) noise | 53 | 53 | 53 | 47 | 34 | 31 | 31 | 48 |
| Typical ambient ($L_{eq}$) noise levels | 51 | 48 | 49 | 43 | 30 | 28 | 25 | 44 |

**Impact Criteria.**

Initial broadband criteria used to select configurations for deeper 1/3 octave analyses are as follows:
Receptor A – Store, shop floor area.
Significant noise impact is considered to be avoided where the ($L_{AFmax}$) from weight drops is measured at or around the prevailing ambient noise level ($L_{AFmax}$) (see Table G3).

Receptor B – Show room Store, staffroom and kitchen area.
Significant noise impact is considered to be avoided where the ($L_{AFmax}$) from weight drops from the adjacent demise is measured at or below the prevailing ambient noise level ($L_{AFmax}$). (See Table G4).

**Receptor A** - Free Weight Impact Testing Results (Figure G1)

*Table G3: Summary of Overall Measured Levels in Receptor A*

| **Configuration** | **Measured $L_{AFmax}$ (dB)** | **Comments** |
|---|---|---|
| Residual Ambient Noise Level | 46 | Store Music OFF |
| | | |
| Typical Ambient Noise Level | 54 | Store Music ON |

| | | |
|---|---|---|
| Bare Floor Weight Drop | 81 | |
| Configuration 1 | 43.9 | |
| Configuration 2 | 44.7 | |
| Configuration 3 | 45 | |



**Receptor B** - Free Weight Impact Testing Results (Figure G2)

*Table G4: Summary of Overall Measured Levels in Show room Store, staffroom and kitchen area.*

| **Configuration** | **Measured $L_{AFmax}$ (dB)** |
|---|---|
| Typical Ambient Noise Level | 46 |
| Bare Floor Weight Drop | 53 |
| 10mm Rubber Floor Finish (RFF) + 40mm Foam | 46 |
| 30mm Rubber Tile + 25mm Foam | 45.1 |
| 45mm Rubber Tile + 25mm Foam | 46 |

**Discussion Free Weight Impact Tests**

Receptor A – Store, shop floor area – On site measurements show that all but 1 of the 11 configurations tested resulted in an overall impact related noise $L_{AFmax}$ level equivalent to the typical ambient conditions. Analysis of the 1/3 octave performance between 20Hz & 100Hz, see Graph F1 (overleaf), shows that the following configurations when compared with the typical ambient noise levels in receptor A, achieve reductions in impact noise transfer that could be considered acceptable in line with the criteria set out in the impact criteria of this report.

Receptor B –Showroom Store, staffroom and kitchen area – On site measurements show that 6 out of the 6 configurations tested resulted in an overall impact related noise $L_{AFmax}$ level equivalent to the typical ambient background. Analysis of the 1/3 octave performance between 20Hz & 100Hz, see Graph F2 (overleaf), shows that when compared with the typical operational ambient noise levels present in all tested configurations should achieve reductions in impact noise transfer that could be considered acceptable in line with the criteria set out in Section 2 of this report.

In summary, Configurations 1, 2 and 3 are considered to reduce noise intrusion from weight drops to the proposed criteria set out in impact criteria for each of the specified receptors.

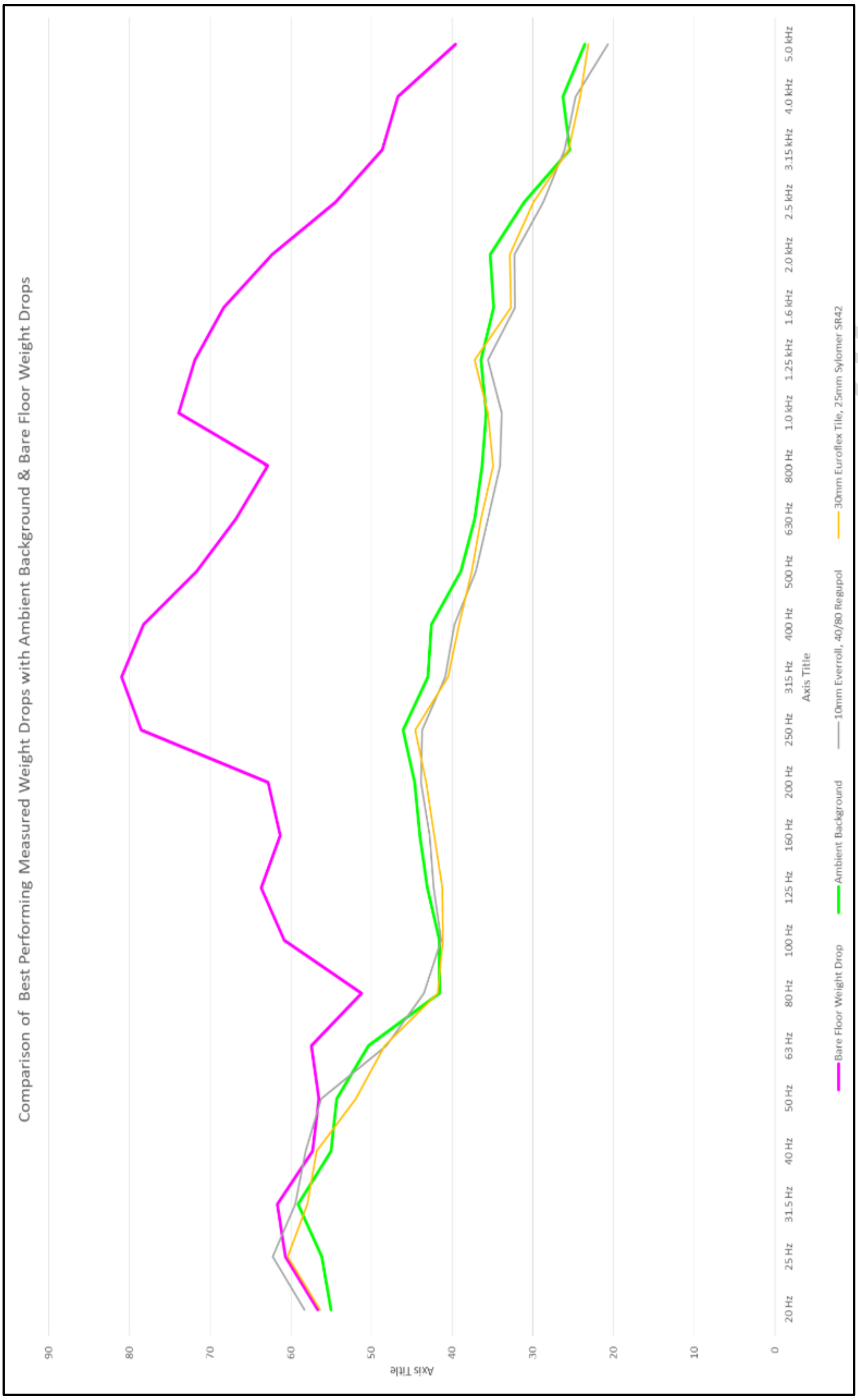



*Figure G1: Comparison of best performing measured weight drops with ambient background & bare floor weight drops*

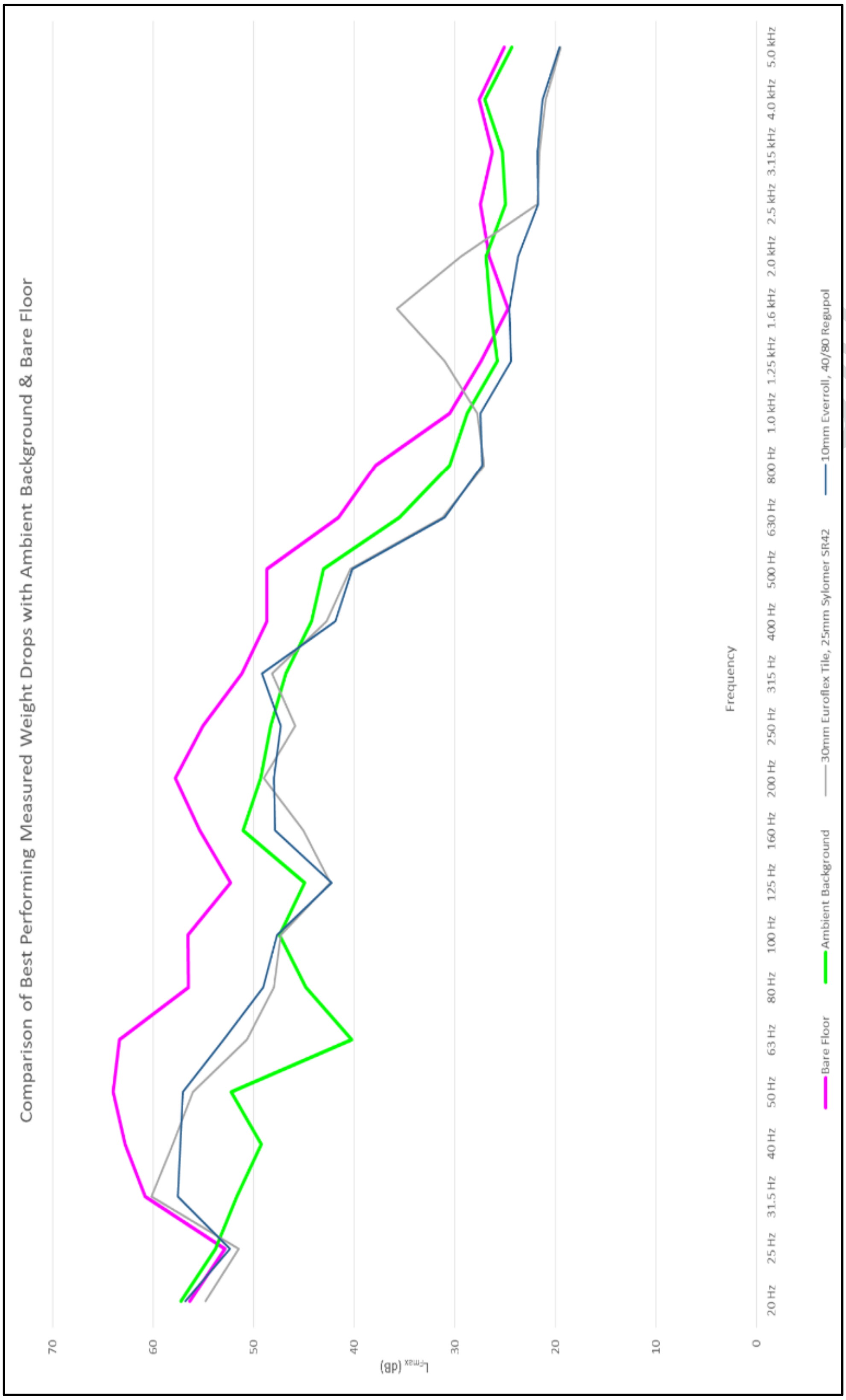



*Figure G2: Comparison of best performing measured weight drops with ambient background & bare floor*

## G.3. Case Study 2: Prediction of Noise Levels beneath a Proposed Gym

The following presents a case study using the prediction methodology presented in Section 4 to predict impact noise from a 35kg weight falling upon a circa 250mm thick concrete floor. The room volume was small, approximately 15m$^3$ with an internal reverberation time estimated to be 0.6s within each third-octave band. The parameters used in the prediction, for each step described in Section 4, are presented below.

*Table G5: Input parameters for prediction model*

| Step | Parameter Required | Value |
|---|---|---|
| 1 | Mass | 35 kg/m$^3$ |
| | Drop height | 1m |
| 2 | Floor density | 2300kg/m$^3$ |
| | Floor thickness | 250mm |
| | Young's modulus | 30x10$^9$N/mm |
| | Poisson ratio | 0.2 |
| 3 | Reverberation Time | 0.6s (at each band) |
| | Speed of sound in air | 343m/s |
| | Density of air | 1.21kg/m$^3$ |
| | Radiation efficiency | 1 (for all bands) |
| | Room volume | 15 |
| 4 | Contact time | 3-7ms |

*Table G6: Summary of results – broadband values*

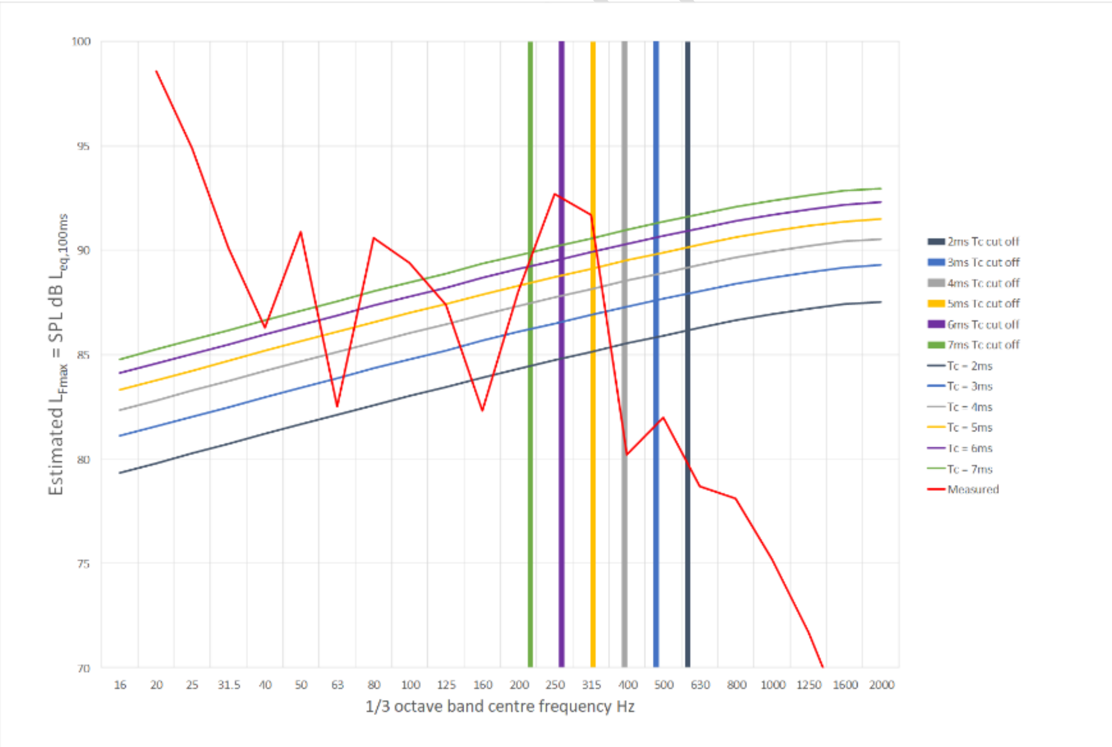
| $T_c$ scenario | $T_c$ cut-off | Measured dB $L_{AFmax}$ up to 2kHz | Predicted dB $L_{AFmax,est}$ up to 2kHz | Difference dB |
|---|---|---|---|---|
| 3ms | 500 Hz | | 89 | 0 |
| 4ms | 375 Hz | | 88 | 0 |
| 5ms | 300 Hz | 90 | 88 | -3 |
| 6ms | 250 Hz | | 85 | -5 |
| 7ms | 215 Hz | | 80 | -4 |

*Table G7: Summary of results – broadband values up to $T_c$*

| $T_c$ scenario | $T_c$ cut-off | Measured dB $L_{AFmax}$ up to $T_c$ cut-off | Predicted dB $L_{AFmax,est}$ up to $T_c$ cut-off | Difference dB |
|---|---|---|---|---|
| 3ms | 500 Hz | 88 | 89 | -1 |
| 4ms | 375 Hz | 87 | 88 | -1 |
| 5ms | 300 Hz | 86 | 88 | -2 |
| 6ms | 250 Hz | 84 | 85 | -1 |
| 7ms | 215 Hz | 82 | 80 | 2 |

The results of the prediction exercise, in terms of re-radiated noise, are provided in Figure G3, for a range of contact times. It can be seen that the prediction serves as a good estimate of the measured response though deviates at low frequencies. Reason for this include the simplified nature of the system, poor modal density and the use of assumed reverberation time values.

*Figure G3: Predicted and measured results*



## G.4. Case Study 3: Assessment using sprung floor system

**Methodology**

Testing was carried out by dropping a 30kg dumbbell at various locations in the ground floor commercial space and measuring the resulting noise levels in the flat above. A number of sprung floor systems (test rigs provided by supplier of floor systems) were tested to determine the potential for noise control mitigation. Details of the sprung floor test rigs and the measurement procedure are set out in the sections below.

**Sprung floor test rigs**

The four floor systems were tested are summarised in Table G8.

*Table G8: Summary of tested floor systems*

| Floor system description |
|---|
| 1 27mm rubber mat |
| 2 4Hz sprung floor system + 27mm rubber mat |
| 3 4Hz sprung floor system + 50mm rubber mat with dimples |
| 4 6Hz formwork sprung floor system + 27mm rubber mat |

Floor system 1 was tested as a baseline case, from which to compare the performance of the sprung floor systems, as dropping the 30kg dumbbell from waist height on directly onto the existing floor which was 150mm PC plank + 50mm screed, receiving room above would have damaged the floor. In any case, this is considered to be a realistic baseline condition for testing as any weights area in a gym would have a durable rubber floor finish (or similar) as a minimum.

**Images of test samples**

*Figure G5: Floor 3 - 4Hz sprung floor system + 50mm rubber mat rubber. Floor 4 - 6Hz formwork sprung floor system + 27mm rubber*



**Measurement procedure**

Synchronised noise measurements were carried out in both the ground floor commercial unit and first floor living room and bedroom in Flat 3. The noise loggers were set to measure levels over contiguous 1second sample periods. The measurements consisted of 1/3 octave band levels stored using various metrics, including $L_{Aeq}$ and $L_{AFmax}$.

A 30kg dumbbell was dropped from a height of 1m onto each of the four tested floor systems. This is considered typical of the height from which weights in a gym would be dropped. The dumbbell drop was repeated five times at each location on each floor system. Five drop locations were established for the tests. In total, 200 impulsive noise event levels were measured in Flat 3 as a result of 100 drops of the 30kg dumbbell.

A sound insulation test was also carried out to determine the acoustic performance of the separating floor between the commercial and residential units. The results of these measurements can be used to quantify the relative contributions of airborne and structure borne noise to the total measured $L_{AFmax}$ levels in the flat.

**Results**

**a) Residual noise in Flat 3**

Residual noise levels in the living room and bedroom of Flat 3 have been determined from the measurements by excluding periods of impulsive noise events related to dumbbell impacts from the time history. The measured residual noise levels are summarised in Table G9.

*Table G9: Residual noise levels in Flat 2*

| Room | Residual noise level, $L_{Aeq}$ (dB) |
|---|---|
| Flat 3 Living room | 39 |

| | |
|---|---|
| Flat 3 Bedroom | 25 |

It is understood that the owner/occupier of Flat 3 has installed secondary glazing in the bedroom to reduce noise ingress from road traffic on the local road system. No remedial secondary glazing has been installed in the living room. Existing noise levels in the living room currently exceed the criteria for good resting conditions, as set out in BS 8233:2014, by 4dB.

*Table G10: Summary of structure borne impulsive noise event levels in Flat 3*

| Floor system | Description | $L_{AFmax}$ (dB) | Attenuation dB(A) | NR (dB) | Attenuation NR |
|---|---|---|---|---|---|
| **1** | 27mm rubber mat (baseline for tests) | 49 | - | 47 | - |
| **2** | 4Hz sprung floor system + 27mm rubber mat | 25 | 24 | 20 | 27 |
| **3** | 4Hz sprung floor system + 50mm rubber mat | 26 | 23 | 21 | 26 |
| **4** | 6Hz formwork sprung floor system + 27mm rubber mat | 32 | 17 | 28 | 19 |