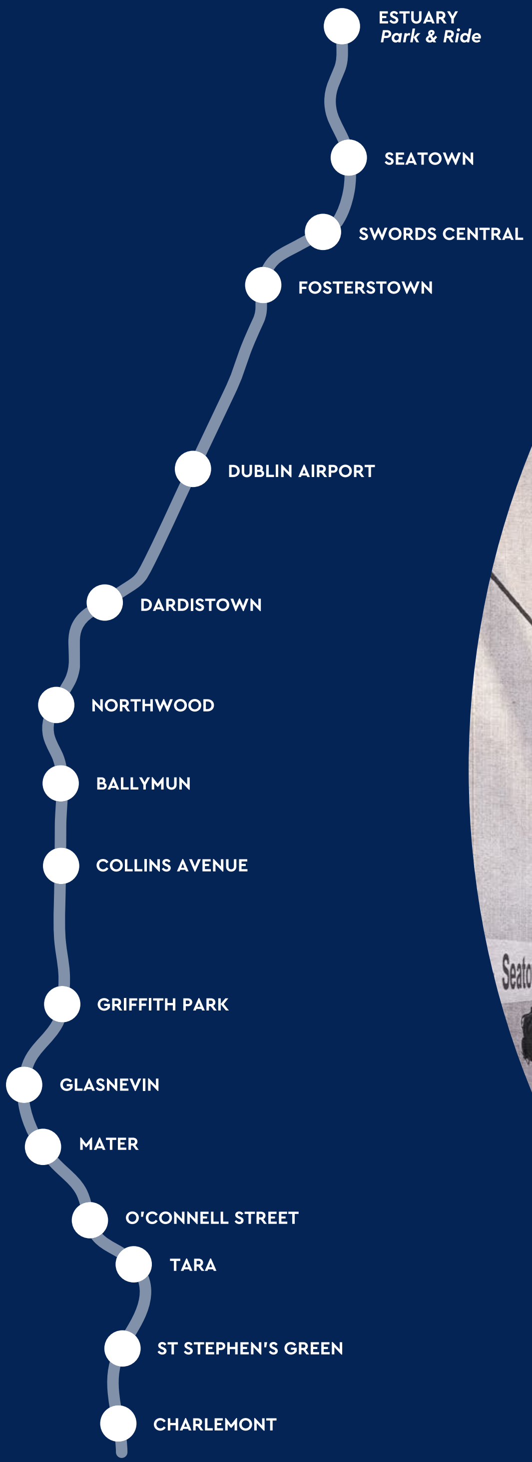


14 Ground-borne Noise and Vibration

Contents

Table of Abbreviations

Acronym	Meaning
AML	Advanced Measurement Laboratory
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BS	British Standard
Ch.	Chainage
DANP	Dublin Airport North Portal
DASP	Dublin Airport South Portal
DCU	Dublin City University
D-wall	Diaphragm wall
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EU	European Union
FDTD	Finite difference time-domain
HVAC	Heating, ventilation, air conditioning
LOD	Limits of Deviation
NIST	National Institute of Standards and Technology
OPW	Office of Public Works
PPV	Peak Particle Velocity
RMS	Root Mean Square
SEM	Scanning Electron Microscopes
TBM	Tunnel Boring Machine
TCD	Trinity College Dublin
UK	United Kingdom
VDV	Vibration Dose Value

14. Groundborne Noise & Vibration

14.1 Introduction

This Chapter of the Environmental Impact Assessment Report (EIAR) assesses the impact of the MetroLink Project (hereafter referred to as the proposed Project), arising from Groundborne Noise and Vibration during the Construction Phase and Operational Phase.

This chapter describes and assesses the likely direct and indirect significant effects of the proposed Project on groundborne noise and vibration, in accordance with the requirements of Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment (i.e. the EIA Directive) (European Union, 2014a).

This Chapter should be read in conjunction with the following Chapters, and their Appendices, which present related impacts arising from the proposed Project and proposed mitigation measures to ameliorate the predicted impacts:

- Chapter 10 (Human Health);
- Chapter 13 (Airborne Noise & Vibration); and
- Chapter 26 (Architectural Heritage).

The assessment is based on identifying and describing the likely significant effects arising from the proposed Project as described in Chapter 4 to 6 of this EIAR. The proposed Project description is based on the design prepared to inform the planning stage of the proposed Project and to allow for a robust assessment as part of the Environmental Impact Assessment (EIA) Process.

Where it is required to make assumptions as the basis of the assessment presented here, these assumptions are based on advice from competent project designers and are clearly outlined within the chapter.

14.1.1 Outline Project Description

A full description of the project is provided in the following chapters of this EIAR:

- Chapter 4 (Description of the MetroLink Project);
- Chapter 5 (MetroLink Construction Phase); and
- Chapter 6 (MetroLink Operations & Maintenance).

Limits of deviation have been set for the proposed Project and this is addressed in the Wider Effects Report annexed at Appendix A5.19.

Table 14.1 presents an outline description of the key proposed Project elements. Diagram 14.1 presents an outline of the main elements of the proposed Construction Phase that are appraised in this chapter and Diagram 14.2 presents an outline of the main elements of the operational phase of the proposed Project that are appraised in this chapter.

Table 14.1: Outline Description of the Principal Project Elements

Project Elements	Outline Description	Groundborne noise and vibration Considerations
Permanent Project Elements		
Tunnels	It is proposed to construct two geographically separate, single-bore tunnels, using a Tunnel Boring Machine (TBM). Each section of tunnel will have an 8.5m inside diameter and will contain both	Construction activities associated with the use of the TBM are assessed as part of the Construction Phase impact

Project Elements	Outline Description	Groundborne noise and vibration Considerations
	northbound and southbound rail lines within the same tunnel. These tunnels will be located as follows: ▪ The Airport Tunnel: Running south from Dublin Airport North Portal (DANP) under Dublin Airport and surfacing south of the airport at Dublin Airport South Portal (DASP) and will be approximately 2.3km in length; and ▪ The City Tunnel: running for 9.4km from Northwood Portal and terminating underground south of Charlemont Station.	assessment. Groundborne noise and vibration from trains within the tunnelled sections are assessed in the Operational phase assessment.
Cut Sections	The northern section of the alignment is characterised by a shallow excavated alignment whereby the alignment runs below the existing ground level. Part of the cut sections are open at the top, with fences along the alignment for safety and security. While other sections are "cut and cover", whereby the alignment is covered.	Vibration from piling in the cut sections is assessed as part of the Construction Phase impact assessment. Groundborne vibration from trains running through cut sections is assessed in the Operational phase assessment.
Tunnel Portals	The openings at the end of the tunnel are referred to as portals. They are concrete and steel structures designed to provide the commencement or termination of a tunnelled section of route and provide a transition to adjacent lengths of the route which may be in retained structures or at the surface. There are three proposed portals, which are: ▪ DANP; ▪ DASP; and ▪ Northwood Portal. There will be no portal at the southern end of the proposed Project, as the southern termination and turnback would be underground.	n/a
Stations	There are three types of stations: surface stations, retained cut stations and underground stations: ▪ Estuary Station will be built at surface level, known as a 'surface station'; ▪ Seatown, Swords Central, Fosterstown Stations and the proposed Dardistown Station will be in retained cutting, known as 'retained cut stations'; and ▪ Dublin Airport Station and all 10 stations along the City Tunnel will be underground.	Construction noise and vibration associated with the construction of the stations are assessed in the Construction Phase section.
Intervention Shaft	An intervention shaft will be required at Albert College Park to provide adequate emergency egress from the City Tunnel and to support tunnel ventilation. Following the European Standard for safety in railway tunnels TSI 1303/2014: Technical Specification for Interoperability relating to 'safety in railway tunnels' of the rail system of the European Union, it has been recommended that the maximum spacing between emergency exits is 1,000m. As the distance between Collins Avenue and Griffith Park is 1,494m, this intervention shaft is proposed to safely support evacuation/emergency service access in the event of an incident. This shaft will also function	Construction noise and vibration associated with the mechanical excavation of the shafts are considered in the Construction Phase section.

Project Elements	Outline Description	Groundborne noise and vibration Considerations
	to provide ventilation to the tunnel. The shaft will require two 23m long connection tunnels extending from the shaft, connecting to the main tunnel. At other locations, emergency access will be incorporated into the stations and portals or intervention tunnels will be utilised at locations where there is no available space for a shaft to be constructed and located where required (see below).	
Intervention Tunnels	In addition to the two main 'running' tunnels, there are three shorter, smaller diameter tunnels. These are the evacuation and ventilation tunnels (known as Intervention Tunnels): ▪ Airport Intervention Tunnels: parallel to the Airport Tunnel, there will also be two smaller diameter tunnels; on the west side, an evacuation tunnel running northwards from DASP for about 315m, and on the east side, a ventilation tunnel connected to the main tunnel and extending about 600m from DASP underneath Dublin Airport Lands. In the event of an incident in the main tunnel, the evacuation tunnel will enable passengers to walk out to a safe location outside the Dublin Airport Lands. ▪ Charlemont Intervention Tunnel: The City Tunnel will extend 360m south of Charlemont Station. A parallel evacuation and ventilation tunnel is required from the end of the City Tunnel back to Charlemont Station to support emergency evacuation of maintenance staff and ventilation for this section of tunnel.	Construction noise and vibration associated with the mechanical excavation of the intervention tunnels are considered in the Construction Phase section.
Park and Ride Facility	The proposed Park and Ride Facility next to Estuary Station will include provision for up to 3,000 parking spaces.	n/a
Broadmeadow and Ward River Viaduct	A 260m long viaduct is proposed between Estuary and Seatown Stations, to cross the Broadmeadow and Ward Rivers and their floodplains.	n/a
Proposed Grid Connections	Grid Connections will be provided via cable routes with the addition of new 110kV substations at DANP and Dardistown. (Approval for the proposed grid connections to be applied for separately but are assessed in the EIAR).	n/a
Dardistown Depot	A maintenance depot will be located at Dardistown. It will include: ▪ Vehicle stabling; ▪ Maintenance workshops and pits; ▪ Automatic vehicle wash facilities; ▪ A test track; ▪ Sanding system for rolling stock; ▪ The Operations Control Centre for the proposed Project; ▪ A substation; ▪ A mast, and ▪ Other staff facilities and a carpark.	n/a

Project Elements	Outline Description	Groundborne noise and vibration Considerations
Operations Control Centre	The main Operations Control Centre (OCC) will be located at Dardistown Depot and a back-up OCC will be provided at Estuary.	n/a
M50 Viaduct	A 100m long viaduct to carry the proposed Project across the M50 between the Dardistown Depot and Northwood Station.	n/a
Temporary Project Elements		
Construction Compounds	There will be 34 Construction Compounds including 20 main Construction Compounds and 14 satellite Construction Compounds required during the Construction Phase of the proposed Project. The main Construction Compounds will be located at each of the proposed station locations, the portal locations and the Dardistown Depot Location (also covering the Dardistown station) with satellite compounds located at other locations along the alignment. Outside of the Construction Compounds there will be works areas and sites associated with the construction of all elements of the proposed Project, including an easement strip along the surface sections.	n/a
Logistics Sites	The main logistics sites will be located at Estuary, near Pinnock Hill east of the R132 Swords Bypass and north of Saint Margaret's Road at the Northwood Compound. (These areas are included within the 14 Satellite Construction Compounds).	n/a
Tunnel Boring Machine Launch Site	There will be two main tunnel boring machine (TBM) launch sites. One will be located at DASP which will serve the TBM boring the Airport Tunnel and the second will be located at the Northwood Construction Compound which will serve the TBM boring the City Tunnel.	n/a

Enabling Works

- Pre-construction surveys and monitoring
- Site establishment and erection of temporary fencing
- Establishment of construction compounds, site office and security
- Site preparation
- Utility diversions
- Vegetation clearance
- Invasive species clearance
- Installation of monitoring systems
- Demolition
- Heritage surveys and preservation
- Establishment of temporary traffic measures

Main civil engineering works

- Excavation, earthworks and construction of structures including stations, tunnels, intervention shafts, cuttings, embankments, bridges and viaducts
- Construction of new roads and access routes
- Road realignments and modifications

Railway systems installation

- Installation of railway track, overhead line equipment, train controls and telecommunication systems
- Installation of mechanical, electrical and operating equipment
- Construction of power supply infrastructure and connection to the electricity transmission grid

Site finalisation works

- Removing construction compounds
- Land reinstatement, such as agricultural land and parks
- Planting, landscaping and erection of permanent fencing

Systems testing & commissioning

- Testing the railway systems
- Commissioning the railway
- Trial running

Diagram 14.1: Summary of Key Activities During the Construction Phase of the Proposed Project

Operational Strategy

- Fully Automated Rolling Stock
- Designed for a maximum of 20,000 passengers per hour per direction
- Minimum possible headway at 100 seconds
- Train will accommodate 500 passengers
- Operational Hours from 05:30 until 0:30

Operational Systems

- Operational Control Centre at Dardistown
- 40 High Floor Vehicles
- Power Systems to supply power to vehicles and stations
- Communication Systems including Radio, WiFi, CCTV, Public Address and Voice Alarm (PAVA), public mobile network and Emergency Telephones
- Ventilation and Air Conditioning Systems
- Emergency Evacuation and Fire Fighting Systems

Maintenance Systems

- Vehicle Maintenance at Dardistown Depot
- Maintenance of Operational Corridor outside of Operation Hours (0:30 until 5:30)
- Maintenance of Power systems, Communication Systems and Ventilation and Air Conditioning Systems

Station Operation

- Access via Escalators, Stairs and Lifts
- Signage
- Ticket Machines
- Lighting
- Back of House
- CCTV and Security

Diagram 14.2: Summary of the Key Activities during the Operation of the Proposed Project

Groundborne noise and vibration are essentially one physical phenomenon which has effects in two different ways. The phenomenon is the oscillatory movement of soil, rock or structures which is generated by construction or operational activity and propagated from the source to potential receptors through solid (or liquid) media.

Sound is vibrations of the air which are detectable by the ear. Sound waves radiate out from a sound source and vary in amplitude and frequency over time. Noise is commonly described as unwanted sound, or sound that causes disturbance.

The term vibration is mainly used when there is a direct effect on a receptor, either a human being perceiving it through the sense of touch or motion or a sensitive item such as a laboratory instrument or a fragile artefact or structure. Vibration can cause structures to radiate airborne sound, in the manner of a loudspeaker, so that it can be perceived by human beings through the sense of hearing as an audible noise, although unlike general environmental noise it reaches the receptor mainly by transmission through the ground and/or a structure and is radiated as sound at the end of the transmission path in the room where the receptor is located.

In exceptional cases, groundborne noise can be heard in the open, above a vibrating ground surface, but nearly always it is the effect within a building that is potentially significant. Vibration as defined above is of interest generally in the low frequency range up to 80Hz, and groundborne noise is of interest in a higher frequency range of about 20Hz-500Hz.

Impacts from blasting are discussed in terms of groundborne noise, vibration and also air overpressure. Air overpressure is a short duration rise in pressure above atmospheric pressure followed by a brief dip below which is heard as sound, but may also cause secondary effects by rattling structures such as windows. It is normal practice to measure it in terms of its un-weighted maximum value, expressed in decibels, although because it has predominantly low frequency content, and is not weighted for the low sensitivity of the human ear to low frequencies, the values of air overpressure expressed in decibels are much higher numbers than normally seen in noise assessments.

14.2 Methodology

14.2.1 Appraisal Method for the Assessment of Impacts

14.2.1.1 Groundborne Noise

Groundborne noise from the construction and operation of the proposed Project has the potential to have an adverse effect on sensitive receptors. The main sources of groundborne noise and vibration from the Construction Phase that have the potential for adverse effects would be mechanical excavation, blasting and tunnel boring. The main sources of groundborne noise and vibration during operation would be from rolling stock movement within the tunnels.

The significance of groundborne noise levels arising from underground activity has been determined from the criteria defined in Table 14.2 for residential dwellings. Impact has been considered significant if groundborne noise levels exceed 40 dB $L_{Amax,S}$. This excludes the passage of the TBM, which is short term and transitory and is accordingly assessed with higher thresholds as described below.

Table 14.2: Groundborne Noise from Underground Sources - Threshold of Significant Effects on Residential Building Occupants

Impact Magnitude	Groundborne Noise Level dB ($L_{Amax,S}$) (measured near the centre of any dwelling room on the ground floor)		Significance of Effect
	Activity except TBM	TBM advancement	
Low	35-39	40-44	Not significant
Medium	40-44	44-49	Significant effect
High	45-49	50-54	
Very High	>49	>54	

Note 1: TBM passage is short term and transitory and has been assessed using thresholds 5dB higher as explained below.

In the case of buildings known to be used as reference libraries, lecture theatres, auditoria, theatres, hospitals, churches, schools and similar buildings, the use of which is particularly sensitive to noise or vibration, significant impacts have been deemed to occur if the levels in the Table 14.3 below are exceeded during the periods of their use.

Table 14.3: Groundborne Noise from Underground Sources - Threshold of Significant Effects on Non-Residential Buildings

Building	Level/ Measure (Activity except TBM)	Level/ Measure (TBM advancement)	Commentary
Theatres	25 dB $L_{Amax,S}$	30 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some during quiet performances.

Building	Level/ Measure (Activity except TBM)	Level/ Measure (TBM advancement)	Commentary
Large Auditoria/Concert Halls	25 dB $L_{Amax,S}$	30 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some during quiet performances.
Studios	30 dB $L_{Amax,S}$	30 dB $L_{Amax,S}$	*Equipment:* Noticeable in recordings.
Churches	35 dB $L_{Amax,S}$	40 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some
Courts, lecture theatres	35 dB $L_{Amax,S}$	40 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some
Small Auditoria/halls	35 dB $L_{Amax,S}$	40 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some
Schools Colleges	40 dB $L_{Amax,S}$	45 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some.
Hospitals, laboratories	40 dB $L_{Amax,S}$	45 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some.
Libraries	40 dB $L_{Amax,S}$	45 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some.
Offices	40 dB $L_{Amax,S}$	45 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some.
Commercial Buildings	45 dB $L_{Amax,S}$	50 dB $L_{Amax,S}$	*Human Response:* Noticeable to all and disturbing to some.

Note 1: Commercial buildings are defined as buildings used for commercial purposes (e.g. shops, restaurants, manufacturing facilities, which may include small back room offices)

The impact of groundborne noise from the TBM will be transient in nature, as it would progress continuously, at a variable rate depending on conditions at a particular location. It would therefore be within range of any particular location for a very limited duration. Based on experience of the driving of the Dublin Port Tunnel and other major tunnelling projects the implementation of a consultation and public relations programme in advance of the works will allow for a higher threshold of acceptability than is the case for the permanent operating railway. As a result a threshold is proposed for groundborne noise from the passage of a TBM 5dB $L_{Amax,S}$ greater than the thresholds for other sources in Table 14.2 and Table 14.3 is proposed for groundborne noise from the passage of a TBM.

14.2.1.2 Vibration

Groundborne vibration from the construction and operation of the proposed Project has the potential to have an adverse effect on nearby sensitive receptors. The main vibration sources from the Construction Phase that have the potential for annoyance would be blasting, TBM advancement, mechanical excavation, secant piling and diaphragm walling (D-walling). During operation rolling stock movement are a potential source of groundborne vibration.

This assessment of the potential effects from vibration have been based on absolute levels and not a change in level. These are broken down into those relating to building damage, annoyance to people and interference with the use of sensitive laboratory equipment. The level of magnitude between human perceptions and building damage are large, and each has separate assessment criteria.

14.2.1.2.1 Vibration from Blasting

For assessment of vibration from blasting, the metric conventionally used is peak particle velocity (PPV). The Environmental Protection Agency in the 2006 "Guidance Note for Noise in Relation to Scheduled Activities, 2nd Edition" recommends that, to avoid any risk of damage to properties in the vicinity, the vibration levels from blasting should not exceed a peak particle velocity of 12 mm/s as measured at a receiving location when blasting occurs once per week or less. However, when the frequency of vibration is less than 10Hz the peak particle velocity should not exceed 8mm/s. In the event of more frequent blasting, the peak particle velocity should not exceed 8mm/s.

The guidance note (EPA, 2006) states that human beings are known to be very sensitive to vibration, the threshold of perception being typically in the PPV range of 0.15mm/s – 0.3mm/s, at frequencies between 8Hz and 80Hz for continuous vibrations, and 0.5mm/s – 1.5mm/s in the case of impulsive vibrations from blasting operations. Vibration nuisance may be associated with the false assumption that, if vibrations can be felt, then damage is inevitable; however, considerably greater levels of vibration are required to cause damage to buildings and structures.

The human response can be greatly reduced by consultation and communication, associated with management of blasting programmes. If populations are aware that blasting will occur precisely at pre-set times and that while it will be momentarily very clearly perceptible it will not cause damage to buildings or structures, it can be possible to achieve a programme of blasting with effects which would not be classified as "significant". On this basis the damage thresholds for the effect of vibration on buildings and structures may be used as the threshold of significance for blasting.

Table 14.4: Construction Vibration - Blasting –– Threshold of Significant Effects on Humans

Category of Impact	Threshold PPV
Human Response: Disturbance	8 mm/s

A significance threshold of 8mm/s PPV is used for standard buildings. For fragile buildings and structures at high risk of damage the threshold of significant effect is taken as 3 mm/s as represented in Table 14.5 below. This is based on the advice contained in the German Standard DIN 4150-3:2016 "Vibrations in buildings – Part 3: Effects on structures". It is assumed that known buildings and structures of this kind will be subject to condition surveys well in advance of the works, and any defects identified repaired (for example, loose panes in stained glass windows). The results of conditions surveys determine whether a building is classed as "vulnerable".

With regard to impacts on utilities, the criteria contained in DIN 4150-3: 2016 have been used. For civil engineering structures such as reinforced concrete constructions used as abutments or block foundations, a value of 80mm/s is used as a guideline value, provided no hazards arise as a result of soil mechanical processes in the ground. For evaluating the effects on linings of tunnels, galleries and cavities in rock, the guideline values are 40mm/s for masonry, 60mm/s for stone and 80mm/s for reinforced and sprayed concrete. It is assumed that the lining has been manufactured and applied using current technology; otherwise, lower values need to be applied. For buried pipework the recommended values are 50mm/s for masonry and plastics, 80mm/s for clay and concrete and 100mm/s for steel. None of the construction activities proposed for MetroLink will have potential to meet these levels of vibration, with the exception of blasting. As a result, the assessment of impacts is presented in this chapter having regard to blasting only.

Table 14.5: Construction Vibration - Blasting - Threshold of Significant Impacts on Structures

Category of Building	Threshold PPV
Standard buildings	8mm/s
Listed or potentially vulnerable buildings	3mm/s

14.2.1.2.2 Air Overpressure from Blasting

The Environmental Protection Agency in the 2006 "Guidance Note for Noise in Relation to Scheduled Activities, 2nd Edition" recommends that blasting should not generally give rise to air overpressure values at sensitive locations which are in excess of 125dB (Lin) max peak, and this value has been taken as the threshold of significance

14.2.1.2.3 *Vibration from Construction Sources other than Blasting*

The thresholds of significant effects on occupants of residential buildings for construction vibration from sources other than blasting are given in Table 14.6. These are based on the guidance in British Standard 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings" and are applicable to both transient and continuous vibration. The thresholds for non-residential buildings are given in Table 14.7 based on criteria adopted by projects such as High Speed 2 in the UK.

Table 14.6: Construction Vibration – Sources Other Than Blasting - Threshold of Significant Effects on Occupants of Residential Buildings

Examples	$VDV_{day}[m/s^{1.75}]$	$VDV_{night}[m/s^{1.75}]$
Dwellings	0.8	0.4

Table 14.7: Construction Vibration - Sources Other Than Blasting - Threshold of Significant Effects on Occupants of Non-Residential Buildings

Examples	$VDV_{day}[m/s^{1.75}]$	$VDV_{night}[m/s^{1.75}]$
Hospital wards; and education dormitories Assisted living, nursing homes, homeless hubs	0.2	0.1
Offices; Schools; and Places of Worship	1.6	n/a
Workshops	3.2	n/a
Vibration sensitive research and manufacturing (e.g. computer chip manufacture); hospitals with vibration sensitive equipment / operations; universities with vibration sensitive research equipment / operations	Risk assessment will be undertaken based on the information currently available for the relevant equipment / process, or where information provided by the building owner or equipment manufacturer	

The thresholds for significant effects on building structures due to transient vibration other than blasting are given in Table 14.8 based on the guidance in BS 7385-2:1993. For continuous vibration the values are reduced by 50%.

Table 14.8: Construction Vibration - Sources other than Blasting - Threshold of Significant Effects on Structures

Structure Type	Allowable Vibration (in terms of PPV) at the Closest Part of Sensitive Property to the Source of Vibration, at a Frequency of 4Hz	
	Transient Vibration	Continuous Vibration
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s	25mm/s
Unreinforced or light framed structures. Residential or light commercial-type buildings	15mm/s	7.5mm/s
Protected and Historic Buildings	6mm/s – 15mm/s	3 mm/s – 7.5mm/s
Identified Potentially Vulnerable Structures and Buildings with Low Vibration Threshold	3mm/s	

With regard to infrastructure, including Iarnród Éireann assets retaining structures, buildings, trackside services, signal structures and utilities, and structure such as canals, assessment is carried out on a case-by-case basis having regard to the criteria in Table 14.8.

The impact of vibration from the TBM advancement would be transient in nature, as the face would progress continuously, at a variable rate depending on conditions at a particular location. It would therefore be within range of any particular location for a limited duration. With the implementation of a consultation and public relations programme a higher threshold of acceptability can be achieved than is the case for the permanent operating railway, and a threshold of 1ms$^{-1.75}$ $VDV_{,day}$ and 0.5ms$^{-1.75}$ VDV_{night} are proposed for dwellings for the passage of the TBM where exceedance of the these thresholds is considered to be significant. For the same reason increases are also proposed for the hospital and education category for the passage of the TBM to thresholds of 0.4ms$^{-1.75}$ $VDV_{,day}$ and 0.2ms$^{-1.75}$ VDV_{night}

14.2.1.2.4 Vibration from Operation

The significance of vibration levels affecting building occupants arising from the operation of the proposed Project has been determined from the criteria defined in Table 14.9, based on the guidance in BS 6472-1:2008.

Table 14.9: Vibration During Operation - Threshold of Significant Effects on building occupants

Impact Magnitiude	In the Absence of Appreciable Existing Levels of Vibration		Appreciable Existing Levels of Vibration (1) (2)	Effect according to BS 6472	Significant?
	VDV ms-1.75 Daytime (07:00-23:00)	VDV ms-1.75 Night-time (23:00-07:00)	% Increase in VDV		
None	≤0.2	<0.1	<25	Adverse comment not expected	Not significant
Negligible	>0.2 – 0.4	>0.1 – 0.2	25 – 40%	Low probability of adverse comment	
Low	> 0.4 – 0.8	> 0.2 – 0.4	> 40 – 100%	Adverse comment possible	
Medium	> 0.8 – 1.6	> 0.4 – 0.8	> 100 –185%	Adverse comment probable	Significant
High	> 1.6	> 0.8	> 185%	Adverse comment very likely	

(1) Highest impact category used, daytime or night-time.

(2) Where there is an appreciable existing level of vibration and daytime and night-time vibration dose values (VDVs) exceed 0.22ms$^{-1.75}$ and 0.13ms$^{-1.75}$

The potential for significant effect upon structures has been deemed to occur if the threshold levels given in Table 14.8 were predicted to be exceeded.

14.2.1.2.5 Vibration from Maintenance – Operational Phase

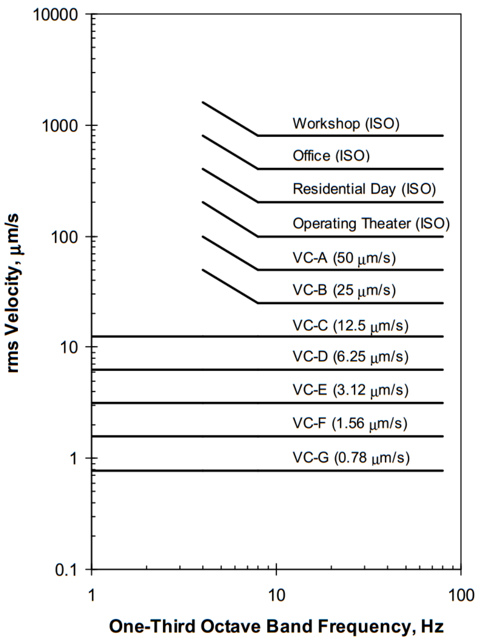
Maintenance of the railway during the operational phase may consist of track-component replacement, signalling and other lineside-equipment maintenance, and rail maintenance including rail grinding (the use of a grinding machine to maintain the rail surface). The need for rail grinding is system-specific, and unforeseeable in its extent and frequency. Some systems need little grinding if there is low propensity for rail corrugation to grow. Others may need it every few weeks. Noise or vibration from rail grinding is normally so infrequent that it is not a significant effect (although it usually takes place at night). Grinding will be managed and mitigated with consultation and good communication with the occupiers of nearby properties.

Rail grinding of underground track is highly beneficial from the point of view of keeping ongoing groundborne noise levels down. When the grinding takes place, there are no effects on the majority of receptors. If grinding were to take place directly beneath laboratories containing sensitive equipment, it would generate measurable vibration. Mitigation includes making sure it is not planned on a night when a critical operation is in progress in a laboratory.

14.2.1.3 Especially Sensitive Receptors – Construction and Operation

Receptors with particular sensitivity to vibration include laboratories containing sensitive equipment such as electron microscopes, and buildings containing fragile artefacts.

A frequently used set of criteria for the effects of vibration on sensitive equipment is the ASHRAE guidelines[1], which are reproduced in Diagram 14.3.



Criterion Curve	Amplitude[1] μm/s (μin/s)	Detail size[2] μm	Description of use
Workshop (ISO)	800 (32 000)	N/A	Distinctly perceptible vibration. Appropriate to workshops and nonsensitive areas.
Office (ISO)	400 (16 000)	N/A	Perceptible vibration. Appropriate to offices and nonsensitive areas.
Residential day (ISO)	200 (8 000)	75	Barely perceptible vibration. Appropriate to sleep areas in most instances. Usually adequate for computer equipment, hospital recovery rooms, semiconductor probe test equipment, and microscopes less than 40x.
Operating theatre (ISO)	100 (4 000)	25	Vibration not perceptible. Suitable in most instances for surgical suites, microscopes to 100x and for other equipment of low sensitivity.
VC-A	50 (2 000)	8	Adequate in most instances for optical microscopes to 400x, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	25 (1 000)	3	Appropriate for inspection and lithography equipment (including steppers) to 3 μm line widths.
VC-C	12.5 (500)	1 – 3	Appropriate standard for optical microscopes to 1000x, lithography and inspection equipment (including moderately sensitive electron microscopes) to 1 μm detail size, TFT-LCD stepper/scanner processes.
VC-D	6.25 (250)	0.1 – 0.3	Suitable in most instances for demanding equipment, including many electron microscopes (SEMs and TEMs) and E-Beam systems.
VC-E	3.12 (125)	< 0.1	A challenging criterion to achieve. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems, E-Beam lithography systems working at nanometer scales, and other systems requiring extraordinary dynamic stability.
VC-F	1.56 (62.5)	N/A	Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation.
VC-G	0.78 (31.3)	N/A	Appropriate for extremely quiet research spaces; generally difficult to achieve in most instances, especially cleanrooms. Not recommended for use as a design criterion, only for evaluation.

[1]As measured in one-third octave bands of frequency over the frequency range 8 to 80 Hz (VC-A and VC-B) or 1 to 80 Hz (VC-C through VC-G).

[2]The detail size refers to line width in the case of microelectronics fabrication, the particle (cell) size in the case of medical and pharmaceutical research, etc. It is not relevant to imaging associated with probe technologies, AFMs, and nanotechnology.

The information given in this table is for guidance only. In most instances, it is recommended that the advice of someone knowledgeable about applications and vibration requirements of the equipment and processes be sought.

Diagram 14.3: ASHRAE and NIST Criteria

For highly sensitive spaces in which submicron processes are carried out, criterion VC-D or VC-E are used. (Both are routinely used worldwide for semiconductor facilities). An alternative is NIST-A which was originally used for 'metrology' laboratory space at the Advanced Measurement Laboratory (AML) of the USA's National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland. NIST-A is more stringent than VC-E at frequencies below 20Hz. Spaces requiring a better environment than can be provided even by a quiet site may have a 'better than NIST-A' environment defined by NIST-A1.

The British Museum adopted VC-D as the most stringent criterion during the construction of The World Conservation and Exhibition Centre built between 2008 and 2014. As shown in Diagram 14.3, the VC-D curve has a flat frequency response in terms of velocity, and its value is 0.00625mm/s at all frequencies.

With regard to sensitive laboratory spaces, the Francis Crick Institute in St Pancras, London, was designed with a general criterion requirement of VC-E, which is 0.003125mm/s or 70dB re 1nm/s.

In this assessment, vibration criteria have been assigned to specific receptors on a case-by-case basis as shown in tables in the following Section 14.3 based on existing building usage. In some cases, the

[1] Sound and Vibration Control, The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE): HVAC Applications (SI Edition), 2007

sensitive equipment that is in use at the time of this assessment may have been superseded by the year of opening of the project with updated equipment.

14.2.2 Overview

The assessment presented within this chapter considers the potential impacts of groundborne noise, vibration and air overpressure.

The assessment of the proposed Project includes the following;

- Baseline noise and vibration measurements at multiple locations along the proposed Project to establish the existing noise and vibration baseline (as described in Section 14.3. of this EIAR);
- A review of standards and guidelines to establish the most suitable criteria for the assessment of impacts;
- Predictions of groundborne noise, vibration and air overpressure in relation to the Construction Phase of the proposed Project;
- Predictions of groundborne noise and vibration in relation to the operational phase of the tunnelled sections of the proposed Project (including cut and cover sections); and
- Recommendations for mitigation measured to reduce, where necessary, any potential groundborne noise and vibration impacts from the proposed Project.

14.2.3 Study Area

The proposed Project covers an extensive linear study area between Estuary, north of Swords and Charlemont Stations via Dublin City Centre. Full details of the Project Description can found be in Chapter 4 (Description of the MetroLink Project).

The study area for the EIAR is split between four distinct assessment zones AZ1 to AZ4 as described in Table 14.10.

Table 14.10: Geographical Split of the Assessment Zones.

Reference	Geographical Split	Description
AZ1	Northern Section	Estuary Station to DANP. It includes the railway crossing on a viaduct over the Broadmeadow and Ward Rivers and associated flood plains. This section will include open, retained cut, and cut and cover sections. Section AZ1 includes the Park and Ride facility at Estuary Station as well as stations at Seatown, Swords Central and Fosterstown.
AZ2	Airport Section	Section AZ2 of the proposed Project includes the ESBN connection and new substations, the DANP, the tunnel underneath Dublin Airport, Dublin Airport Station and DASP and associated intervention and ventilation tunnels.
AZ3	Dardistown to Northwood	Section AZ3 of the proposed Project covers from south of DASP to the Northwood Portal. Section AZ3 includes Dardistown station, the Dardistown Depot, ESBN connection and substations, the M50 Crossing, Northwood station and the TBM launch site at Northwood. This section will include open, retained cut, and cut and cover sections of the alignment.
AZ4	Northwood to Charlemont	Section AZ4 extends from a location south of the Northwood Portal to the tunnel termination located south of Charlemont Station, ten underground stations, and the Albert College Park Intervention shaft.

The assessment of noise and vibration from the project is separated into two EIAR Chapters. Chapter 13 considers airborne noise and vibration, and this Chapter 14 considers groundborne noise and vibration. Table 14.3 outlines the various sources of noise and vibration, and which chapter presents the corresponding assessment.

Table 14.11: Noise Sources and Assessment Chapter

Construction Phase	AZ1	AZ2	AZ3	AZ4
Airborne **Chapter 13 of EIAR**	Park & Ride Facility Cut and cover Above ground track laying Stations and platforms Construction compounds Utility diversion works Construction traffic	DANP Dublin Airport station DASP Utility diversion works Construction of intervention shafts, ventilation shafts and tunnel Construction traffic	Dardistown Depot Dardistown Station Above ground track laying M50 Viaduct Northwood TBM launch site compound Northwood station Construction traffic	Station boxes Heavy rail interchange and rail realignment works at Glasnevin Intervention shaft at Albert Park College Park Utility diversion works Construction of intervention tunnel at Charlemont Construction traffic haul routes
Groundborne **Chapter 14 of EIAR**	n/a	Tunnelling using TBM	Blasting (Air overpressure)	Tunnelling using TBM
		Mechanical excavation using road header and D-walling		Mechanical excavation using road header and D-walling
		Blasting (Air overpressure)		Blasting (Air overpressure)
Operation Phase	**AZ1**	**AZ2**	**AZ3**	**AZ4**
Airborne **Chapter 13 of EIAR**	Above ground electricity substations			
	Road traffic			
	Surface stations and retained cut sections Overground airborne railway noise Park and Ride	Ventilation systems serving underground stations and intervention shafts	Dardistown station and depot Overground airborne railway noise	Ventilation systems serving underground stations and intervention shafts
Groundborne **Chapter 14 of EIAR**	Train operation groundborne noise			

Table 14.12: Vibration Sources and Assessment Chapter

Construction Phase	AZ1	AZ2	AZ3	AZ4
Airborne **Chapter 13 of EIAR**	Ground breaking Excavation Demolition	Ground breaking Excavation Demolition	Ground breaking Excavation Demolition	Piling Ground breaking Excavation Demolition
Groundborne	Secant piling along R132	Tunnelling using TBM	Blasting	Tunnelling using TBM

Construction Phase	AZ1	AZ2	AZ3	AZ4
Chapter 14 of EIAR		Mechanical excavation using road header and D-walling		Mechanical excavation using road header and D-walling
		Blasting		Blasting
Operation Phase	**AZ1**	**AZ2**	**AZ3**	**AZ4**
Airborne Chapter 13 of EIAR	n/a			
Groundborne Chapter 14 of EIAR	Train operation vibration			

For the assessment of groundborne noise and vibration the study areas are dynamic for each source of noise or vibration, with impacts calculated as far from the works as needed to identify any adverse impacts in consideration of noise or vibration impact thresholds.

14.2.4 Relevant Guidelines, Policy and Legislation

There are no statutory standards in Ireland relating to noise and vibration limit values for railway sources or construction works. In the absence of specific statutory Irish guidelines, the assessment makes reference to other national guidelines and standards, where available, in addition to international standards relating to noise and or vibration impact for environmental sources. These are summarised below:

- The Environmental Protection Agency (EPA) 2006 has published a Guidance Note for Noise in Relation to Scheduled Activities 2nd Edition. This includes guidance on vibration from blasting.
- A summary of international guidance and other information is given in the book "Measurement and Assessment of Groundborne Noise and Vibration" 3rd edition published by the Association of Noise Consultants in the UK in 2020.
- There is guidance in three parts of ISO 14837 "Mechanical vibration - Ground-borne noise and vibration arising from rail systems", namely:

- ISO 14837-1:2005 "Mechanical Vibration-Ground-borne noise and vibration arising from rail systems-Part 1: General Guidance"
- ISO/TS 14837-31:2015 "Mechanical vibration - Ground-borne noise and vibration arising from rail systems-Part 31: Guideline on field measurements for the evaluation of human exposure in buildings." and
- ISO/TS 14837-32:2015 "Mechanical vibration - Ground-borne noise and vibration arising from rail systems-Part 32: Measurement of dynamic properties of the ground."

- Vibration is assessed in the UK by means of the Vibration Dose Value (VDV) which is defined in BS 6472-1:2008 "Guide to evaluation of human exposure to vibration in buildings".
- German Standard DIN 4150-3:2016 "Vibrations in buildings – Part 3: Effects on structures"

There is no equivalent standard for groundborne noise, but the convention has been established that groundborne noise is assessed in terms of the maximum A-weighted sound level using the index L_{pASmax}. This approach was subject to scrutiny by the specialist assessor in the Oral Hearings for Old Metro North and the Dart Underground and considered appropriate. It has also been used in the UK for schemes including Crossrail (Elizabeth Line) and High Speed 2 where it underwent scrutiny in Parliamentary Select Committees.

Vibration Dose Value is based on weighted acceleration and is dependent on the number and duration of events. However, if vibration velocity does not exceed a continuous rms level of 0.5mm/s throughout an 8-hour night it will not be likely to exceed $0.1ms^{-1.75}$ VDV.

Vibration effects on building fabric are the subject of the British Standard BS 7385-2:1993 Evaluation and Measurement for Vibration in Buildings.

Relevant guidance and standards are listed in Appendix A14.1.

14.2.5 Assessment Methodology

14.2.5.1 Assumptions

Table 14.13 below outlines the Construction Phase elements that are modelled and subsequently assessed for potential Groundborne Noise & Vibration effects.

Table 14.13: Assessment Assumptions for Groundborne Noise & Vibration

Construction Assumptions	Location
Tunnel construction will be carried out primarily by TBM	TBM will progress along entire city tunnel and airport tunnel alignment.
Drill-and-blast will be used	All underground stations and intervention tunnels.
Mechanical Excavation	At all station sites, along cut, cut and cover sections.
The TBM will not be serviced by a temporary construction railway, but instead conveyors will be used for the transfer of materials from the TBM and out of the tunnel Rubber tyred vehicles will also be used for the transportation of material and people.	All underground tunnel sections.
Construction of underground station boxes using diaphragm wall construction	All underground station locations
Top-down construction for cut-and-cover tunnels, and some cut and cover station boxes using secant piling.	Cut and cover tunnel sections in AZ1 and some underground station boxes.
Track laying	Not significant from a groundborne noise & vibration perspective. This is covered in Chapter 13 Airborne Noise & Vibration.
MetroLink routes	Not significant from a groundborne noise & vibration perspective.
No percussive piling will occur	N/A
No significant SCL breakout is planned	N/A
Operation Assumptions	
Trains to be operated in the system would have the characteristics set out in Appendix A14.2. The rolling stock properties that have been assumed for the purpose of modelling and predicting likely levels of groundborne noise and vibration are typical of extant examples of vehicles in current operation on comparable systems.	Along entire alignment
For the purposes of modelling the track support system has been assumed to be a heavy booted block (or equivalent) design. The properties which have been assumed are set out in Appendix A14.3. Section 14.5 of the chapter details further mitigation measures were required to mitigate identified noise & vibration effects.	Along entire alignment

At O'Connell Street Station there are two potential scenarios for construction:

- Where the Dublin Central development proceeds in advance of the proposed Project. In this case the Dublin Central contractor would construct the station box in advance of the MetroLink project.
- Where the MetroLink project proceeds in advance of the development of any oversite development.

In either scenario the groundborne noise and vibration effects would not be expected to differ from those presented in this assessment. Noise and vibration during the construction of the oversite development is discussed in Chapter 13 (Airborne Noise & Vibration).

14.2.5.2 Construction Phase

Groundborne noise and vibration may potentially arise due to the following construction activities: excavation of the tunnel using a TBM; excavation of rock and soil from shafts and station boxes by means of drilling and blasting and/or mechanical excavation; insertion of diaphragm walls and/or secant piles at station boxes; and excavation of intervention tunnels.

14.2.5.2.1 General

Groundborne noise and vibration from the use of the TBM during the Construction Phase has been calculated using the numerical modelling *FINDWAVE®* which is a finite difference time-domain (FDTD) numerical model for computing the propagation of waves in a visco-elastic media, proprietary to Rupert Taylor Ltd (the author). The methodology is presented in detail in Appendix A14.4.

Predictions of vibration from construction sources has been carried out following the procedure identified in Transport Research Laboratory Report 429 on "Ground-borne vibration caused by mechanised construction works." and BS 5228: BS 5228-2:2009+A1:2014, "Code of practice for noise and vibration control on construction and open sites".

14.2.5.2.2 Drilling and Blasting

The principal source of vibration from drilling and blasting is the detonation of explosive charges underground. Vibration is a well-known effect of blasting and the relationship $PPV= K\ W^{d}R^{-b}$ is commonly used to predict peak particle velocity as a function of distance and charge weight per delay. In this expression K is the Ground Transmission Constant, depending on the nature of the rock or soil and other parameters such as confinement. It will also be dependent on the blasting method, with specialist techniques used in tunnelling such as Penetrating Cone Fracture likely to give different results from conventional explosives. W is the charge weight per delay in kilogrammes, and R is the distance in metres, with d and b being empirical exponents. Blasting normally involves a sequence of detonations of small charges, separated by delays of 50 milliseconds or more. W relates to the mass of the explosive detonated after each delay. W and R are often combined in a parameter called scaled distance (S), where $S=R/\sqrt{W}$, in which case the expression becomes $PPV=K\ S^{-b}$. This effectively sets the value of d as 0.5b.

This relationship was originally derived for quarry blasting and has been extended for use in drill and blast operations. Values for K range from 200 to 1200 (for results in mm/s), the latter being for granitic and volcanic rocks, with soft rocks being in the range 500-600. In limestone, the value of K can be expected to be less than in volcanic rock. Monitoring of drilling and blasting for the Dublin Port Tunnel gave results from which parameters can be derived (The Blasting Report is provided as Appendix A5.20).

Based on information reported in the Blasting Strategy Report (Refer to Appendix A5.20), contours of vibration from blasting in terms of ground surface free-field PPV have been produced using a maximum instantaneous charge per delay (MIC) of 0.375kg, K=1133 and b=1.495. These parameters relate to the 95-percentile confidence band, meaning that 2.5% of results would lie above the resulting curve.

14.2.5.2.3 Air Overpressure

In addition to the vibration caused by blasting, an accompanying effect is a pulse of air pressure above and below atmospheric pressure, known as air overpressure. This may be heard as audible sound but also may move structural elements such as windows and cause secondary effects including rattling. It is measured in terms of pressure units in Pascals, using the decibel scale with 20 microPascals as the reference. It is not subject to A-weighting as is the case for noise in general and contains significant low-frequency content so that the numerical values of air overpressure are high in the context of environmental noise levels in dB(A).

The method used for the prediction of air overpressure is analogous to that for ground vibration, except that the scaled distance uses the cube root of the MIC. As with vibration, a K constant is chosen as well as an exponent. The values of K and b are dependent on site conditions, and in the technical literature they vary widely. For the contours produced in the EIAR constants have been taken from the handbook of the International Society of Explosives Engineers, 18th edition, which in turn refers to the work of L.L. Oriard, "Explosives Engineering Construction Vibrations and Geotechnology". The constants used are proposed in the ISEE Handbook for "Construction (Highly Confined)" and are K=2.48 and b=-1.1.

Predictions of air overpressure have been made for two different scenarios representing the level of confinement of the blast. These are 'average burial' and 'highly confined' where the 'highly confined' scenario reduces the levels of air overpressure at nearby receptors.

14.2.5.2.4 Mechanical Excavation

Mechanical excavation will be carried out in various locations of the proposed Project construction. There are different methods available for this activity that could include the use of hydraulic pecker or milling machine/road header. A sensitivity test of these potential methods has been carried out for receptors closest to areas of mechanical excavation. As an example, predictions of groundborne noise during the use of hydraulic breakers at Dublin Airport buildings would be in excess of 50dB $L_{Amax,s}$, which exceeds the 40dB threshold for a significant impact at receptors. The use of a milling machine/road header at the same location results in predicted levels that are below the 40dB threshold. Given the margin of at least 10dB above the groundborne noise threshold for significant impacts the assessment presented in this chapter for mechanical excavation assumed the use of road headers/milling machines only, with no use of hydraulic breakers.

Where rock excavation is carried out by means of mechanical excavation using a milling machine/road header, vibration and groundborne noise has been predicted based on measurement results published in connection with similar excavation work in sandstone in Sydney, Australia (West Connex Transurban M4-M5 Link EIS, Appendix J. Figure 4-2 (AECOM, 2017)) shown in Diagram 14.4. The noise level in Figure 14.3 is stated as L_{Aeq}, but it is assumed this is the L_{Aeq} value while milling is in operation, in which case L_{Aeq} and L_{ASmax} will be very similar in value.

Mechanical excavation is also part of the process of inserting diaphragm walls where these extend down into the rockhead, when a hydrofraise is employed. The cutting head of a hydrofraise is similar to that of a road header, although not necessarily as large, and the contours of groundborne noise from mechanical excavation may be taken as the envelope of groundborne noise levels from diaphragm wall construction as well as mechanical excavation of rock within the station boxes.

The contours of groundborne noise are presented in terms of maximum noise level in dB(A), and the duration of the noise will depend on whether mechanical excavation is used as a full substitute for blasting or as a means of removing rock not dislodged after blasting has taken place. The contours extend around each station box and therefore represent the envelope of maximum levels, with the precise noise level on any day depending on the position of the source at the time.

In addition to the contours of groundborne noise, vibration has also been considered for individual receptors both in terms of VDV for the assessment of human response, and root mean square (RMS) velocity and acceleration where effects on sensitive laboratory equipment is present.

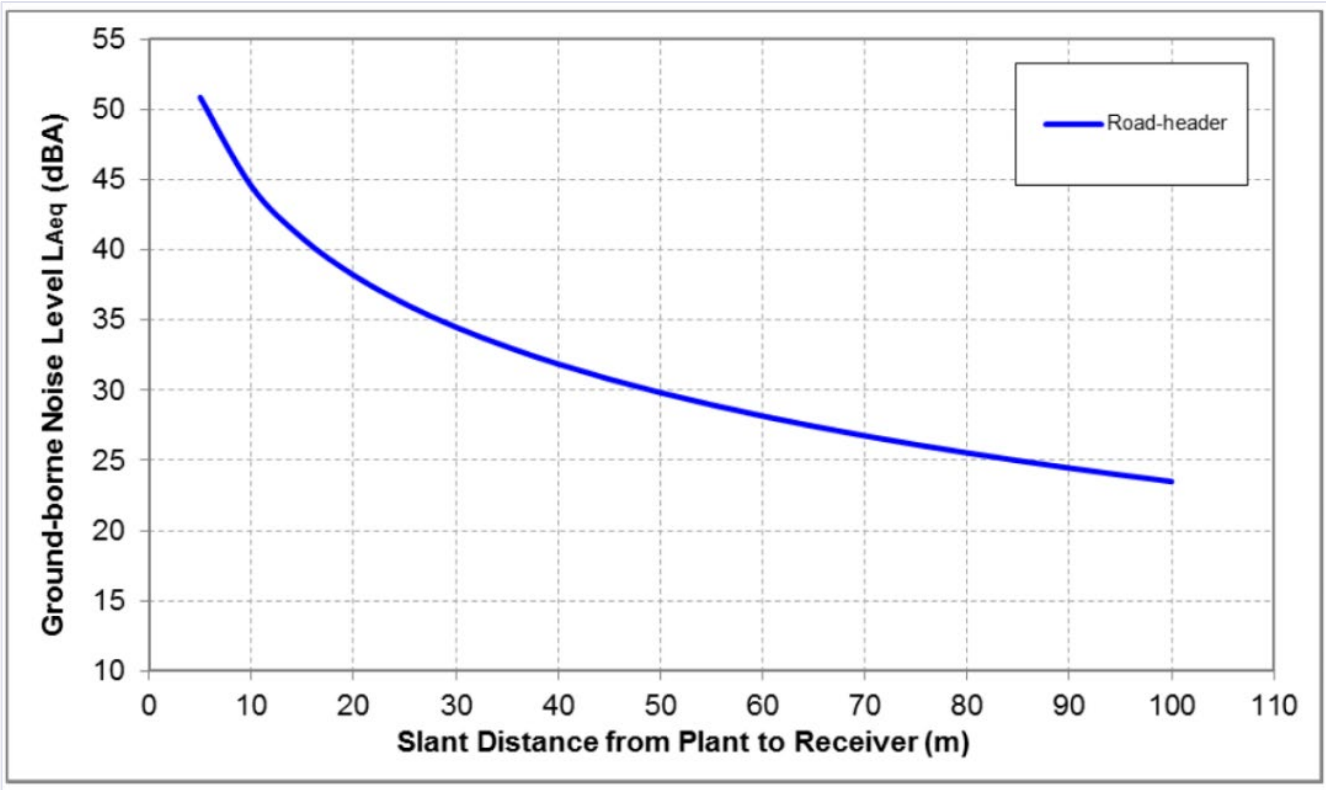


Diagram 14.4 Indicative Groundborne Noise Levels from Road Headers

(Source: West Connex Transurban M4-M5 Link EIS, Appendix J. Figure 4-2 (AECOM, 2017))

14.2.5.3 Operation

Groundborne noise from the underground railway has been predicted using *FINDWAVE®*, which is explained in Appendix A14.4. Its principal use is for the modelling of railway noise and vibration, and it has been used to model the vibration from the railway at grade and in the underground tunnel, including the transmission of groundborne noise and vibration from the tunnels to the ground surface and into buildings.

The railway implementation of *FINDWAVE®* contains two principal (mutually interacting) modules, the train module, and the track/structure/environment module. The train module represents the train as a stack of damped masses and springs representing the rail vehicle. The excitation is provided from an input file containing either a measured or assumed vertical railhead profile, together with the gravitational effect of the rolling train. The train moves in the model and the location of the contact patch for each wheel is constantly advancing (re-entering the model at the front when it goes beyond the end).

The track/structure/environment module models the dynamic behaviour of the track and structure supporting the train, and the medium surrounding it, e.g. soil or air, together with structures below or above ground level. The structures concerned are represented as cells in a 3-dimensional orthogonal grid, each cell being assigned density, Lamé constants and loss factor.

For the proposed Project, *FINDWAVE®* has primarily been used to predict groundborne noise levels in terms of $L_{Amax,S}$ arising from the operational railway in buildings above the tunnel. The $L_{Amax,S}$ is the maximum noise level with A-weighted frequency response and slow time constant. These include residential property and other buildings with special uses such as theatres etc., which are also deemed to be noise sensitive. Predictions have been made for the location within the building concerned, where the greatest noise or vibration is likely to be experienced, usually the basement if that has a noise/vibration-sensitive use.

The predicted levels are compared with the assessment criteria detailed in Table 14.2 and, where impacts are predicted, mitigation to the rail support system has been recommended to minimise subsequent impacts.

Two levels of assessment have been undertaken. Firstly, contours of groundborne noise were generated for the entire alignment, making standard assumptions about building designs (no deep or piled foundations) and simplified soil assumptions. Secondly, individual calculations for buildings with deep or piled foundations have been made.

14.2.5.4 Identification of Potential Effects

14.2.5.4.1 Construction Phase

The Construction Phase activities that are within the scope of this chapter are listed in Table 14.14 below.

Table 14.14: Construction Activities Considered

Activity	Rationale
Tunnel Boring	Potential source of vibration and groundborne noise impacts which may extend up to a plan distance of 100m either side of the tunnel if not mitigated.
Rock Excavation – blasting	Perceptible effects for people could occur up to a distance of 250m if not mitigated. Effects on highly sensitive laboratory equipment could occur at up to 1000m if not mitigated Groundborne noise considered within a range of 100m
Rock excavation – mechanical excavation using road headers, including diaphragm walling,	Excavation by means other than blasting, including road headers, is also a source of vibration and groundborne noise, a range of 100m is considered

The highest potential impact arising during the Construction Phase, if not mitigated would be from blasting. The vibration impact of blasting is dependent on the method used, and in particular the maximum instantaneous charge weight.

Vibration impacts from other construction sources will include impulsive vibration that may occur intermittently during diaphragm wall construction (for example demolition of guide walls). The range of potential impacts for most receptors is approximately 100m from the source, or 100m for auditoria.

14.2.5.4.2 Operational Phase

Vibration is unlikely to have impacts on human beings, whether at grade or in tunnel. However, the operation of the rail line could affect highly sensitive equipment up to a distance of 100m. Groundborne noise is unlikely to have an impact beyond 50m from an operating rail line at grade or in tunnel, although recording studios or performance spaces may require consideration up to 100m.

14.2.5.4.3 Model Uncertainty

The predictions of groundborne noise and vibration provided in this assessment of groundborne noise and vibration are subject to uncertainty (as are all predictions). The magnitude and causes of the uncertainty depend on the type of model used - deterministic or empirical.

The model used to predict groundborne noise and vibration from the operation of rail vehicles is deterministic and subject to the small, known, uncertainties associated with finite-difference-time-domain modelling. The uncertainties are primarily related to the accuracy of the input parameters assumed. Of the parameters most likely to vary from the assumed values, the most important is wheel/rail roughness. Should conditions arise in which the quality of the running surfaces deteriorates, particularly in the case of corrugation growth, levels of groundborne noise and vibration will be much greater than those predicted here in Chapter 14. However, it is assumed that a maintenance regime will be in place such that, should wheel or rail toughness exceed normal amplitudes, intervention in the form of rail grinding will take place and this will restore the actual levels to values no worse than those assumed.

The predictions of TBM vibration and groundborne noise are also deterministic but have an empirical input term based on field measurements obtained during the tunnel drive of the Dublin Port Tunnel. Since those measurements were made in local lithological conditions the associated uncertainty is low.

Some source parameters cannot be known precisely at this stage and procurement of components such as rail vehicles will not take place until after grant of the Railway Order. However, in the course of selecting modelling parameters the characteristic of many rail vehicles operating on similar systems were reviewed and the conclusion reached that the assumptions made in the modelling provide predictions that are unlikely to be exceeded materially.

The degree of detail taken into account in predicting the specific response of individual buildings varies according to the sensitivity of the building and its contents, and the availability of construction details. At Trinity College Dublin examples of the most sensitive cases were fully modelled in three dimensions, whereas in many other cases typical assumptions were made concerning coupling loss factors and building response, with associated uncertainty.

Fully empirical prediction methods have been used with respect to rock excavation, and data taken from publicly available reports on other projects, particularly in Sydney, Australia. There are differences between the lithology of Sydney and Dublin, the former being primarily sandstone and the latter limestone. Although the sandstone of Sydney is slightly harder than the limestone of Dublin, measurements of a TBM operating in the sandstone of Sydney are similar (after allowing for the different diameters) to the predictions that have been made for the TBM operating in the limestone of Dublin. Based on this the groundborne noise and vibration associated with excavation in the two lithologies either by use of road-headers or hydraulic breakers is assumed to be similar.

With regard to blasting, use has been made of data published by the International Society of Explosives Engineers. Uncertainty with regard to amplitudes of the two effects of blasting relevant to this assessment is limited by the fact that the source parameters are within the control of the operator and based on local test blasts to be carried out at the start of the construction programme; limits on maximum instantaneous charge weight and depth of burial of charges will be determined.

It is possible to quantify the probability distribution of uncertainties in prediction work of this kind, for example by the use on Monte-Carlo methods. Based on the authors' experience of applying these methods, it is concluded that for individual receptors, deviations between predicted and out-turn results are likely to have a Gaussian distribution with the 95 percentile being a factor of two (i.e. 6dB where the index used is decibel based). This would mean that there is a 2.5% probability of the out-turn result being more than twice (6dB above) the predicted value.

14.2.5.4.4 Temporal Scope

For the Construction Phase, the activities within the scope of this chapter are listed in Table 14.14 and will occur as presented in the indicative construction programme outlined in Chapter 5 Construction Phase and Appendix A5.2. The programme recognizes that assessment will cover multiple activities at different locations and timeframes, sometimes overlapping.

The temporal scope has also taken into account the time of day during which most construction works would be undertaken, and this has included the following periods: 07:00 to 19:00 hours (day); 19:00 to 23:00 hours (evening); and 23:00 to 07:00 hours (night). Where Saturday morning periods are relevant a 6-hour period (07:00 to 13:00hrs) is considered.

The TBM is a different case, where the basic assumption is that it will operate 24 hours per day, seven days per week. Works at Glasnevin Station will also be undertaken 24 hours and seven days per week. (Section 5.3.1 of Chapter 5: MetroLink Construction Phase, details working hours for the proposed Project).

The Opening Year for the proposed Project is 2035, and the assessment considers the number of trains that are planned to be in operation upon opening of the proposed Project in 2035. The service pattern of the proposed Project is outlined in Chapter 6 (MetroLink Operations & Maintenance), with operating hours of the service starting at 05:30 each day and ending at 00:30 each day.

Of the assessment metrics employed, the only one which is sensitive to the number of trains operating is VDV, and for the calculation of VDV it has been assumed that between Estuary Charlemont 876 two-way trains will operate between 0700 and 2300, and 90 two-way trains will operate between 2300 and 0700.

14.2.6 Consultations

For the purposes of the EIAR, consultations were undertaken to collect and collate information on the sensitivity of buildings along the alignment to vibration (and settlement) having regard to the following:

- Building/structure types and vulnerability to damage due to vibration (or settlement);
- Human activity and vulnerability to groundborne noise and vibration; and
- The use of sensitive equipment that may be impacted by groundborne noise and vibration.

A letter and questionnaire were sent to non-residential properties along the alignment to collect data required. Following this consultation, site specific consultation was also undertaken at a number of specific locations including the following:

- Hertz;
- Siemens;
- O'Scanaill Veterinary Hospital;
- Dublin Airport Authority;
- Mater Hospital;
- Rotunda Hospital;
- Gate Theatre;
- Trinity College Dublin (TCD);
- The Office of Public Works (OPW) on buildings in their charge;
- Dublin Diocese with regard to churches in close proximity to proposed station locations;
- The Department of Culture Heritage and the Gaeltacht; and
- Dublin City Council.

Consultation with all relevant authorities, organisations and stakeholders will continue throughout the assessment and design process. (Refer to Chapter 8: Consultation for more detail).

14.3 Baseline Environment

Vibration (including resultant groundborne noise) in the environment is normally unmeasurable, except in the vicinity of operating rail lines (including tramways) or industrial sources. While vibration may exist near to construction sites, this is of transient nature and not normally considered as relevant in the context of the baseline for an environmental assessment. Vibration can be caused by road vehicles, this also normally only measurable either at very close distances to a highway or in cases where there is a defect in the paving or the formation which would not be considered a permanent feature of the environment. Within buildings, the largest source of baseline vibration is usually footfalls and door closures. While these sources are generally not taken into account in characterising the baseline environment, they are picked up in surveys of baseline vibration in buildings containing especially sensitive equipment.

14.3.1 Sensitive Receptors

The environment within the study area includes a range of receptors, from residential buildings through commercial installations to buildings with special sensitivity to groundborne noise and vibration. Almost all of the residential buildings have simple foundations without basements. Some buildings have basements, and larger buildings have piled or other deep foundations. There are buildings with special sensitivity to groundborne noise and vibration include research laboratories, medical laboratories in hospitals, recording studios, auditoria and other chambers for listening and broadcasting. Examples of known buildings in these categories is given in the sections below, discussed by geographical area.

14.3.1.1 Sensitive Receptors AZ1 Northern Section

There are a range of sensitive receptors in the vicinity of the works in AZ1 that include multiple residential dwellings, several schools and places of business that contain electronic equipment. Examples of the different receptors in the area of AZ1 and in the vicinity of the proposed Project are shown in Table 14.15 together with the applicable noise and vibration assessment thresholds.

Table 14.15: Assessment Locations and Thresholds for AZ1 Northern Section

Building/location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration					Air overpressure (blasting)
					Blasting mm/s PPV	Construction $ms^{-1.75}$		Operation $ms^{-1.75}$ $VDV_{b,day}$		
		TBM Passage	Mechanical Excavation	Operation		VDV_{day}	VDV_{night}	VDV_{day}	VDV_{night}	
Residential	Estuary Court; Ashley Avenue, Seaview Bungalow, Seaview Mews, Fingal House Nursing Home.	N/A	40	40	8	0.8	0.4	0.8	0.4	125
Vet Hospital	O'Scanaill Veterinary Hospital	N/A	40	40	8	0.8	n/a	0.2	n/a	125
Offices	Hertz (customer services centre); Fujitsu Ireland Limited	N/A	40	40	8	1.6	n/a	0.8	n/a	125
Healthcare	Tara Winthrop Private Clinic	n/a	40	40	8	0.2	0.1	0.2	0.1	125
Commercial Buildings	Woodies DIY	n/a	45	45	8	1.6	n/a	1.6	n/a	125
Existing Utilities	All along alignment	n/a	n/a	n/a	50	50mm/s PPV				n/a

14.3.1.2 Sensitive Receptors AZ2 Airport Section

Aside from the airport buildings, there is a single sensitive receptor in the vicinity of the tunnel within the Airport Section. This is the Our Lady Queen of Heaven church. The assessment criteria applicable to the church is given in Table 14.16.

Table 14.16: Assessment Locations and Thresholds for AZ2 Airport Section

Building /location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration			Air overpressure (blasting)
		TBM Passage	Mechanical Excavation	Operation	Blasting mm/s PPV	Construction $ms^{-1.75}$ VDV_{day}	Operation $ms^{-1.75}$ VDV_{day}	
Church	Our Lady Queen of Heaven Church	40	35	35	3	1.6	0.2	125
Offices	Dublin Airport Buildings	45	40	40	8	1.6	0.8	125
Existing Utilities	All along alignment	n/a	n/a	n/a	50	50mm/s PPV		n/a

14.3.1.3 Sensitive Receptors AZ3 Dardistown to Northwood

In the vicinity of the route in AZ3 there are a handful of residential properties, as listed in Table 14.17, together with the applicable noise and vibration assessment thresholds.

Table 14.17: Assessment Locations and Thresholds for AZ3 Dardistown to Northwood

Building / Location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration					Air overpressure (blasting)
					Blasting mm/s PPV	Construction $ms^{-1.75}$		Operation $ms^{-1.75}$		
		TBM Passage	Mechanical Excavation	Operation		VDV_{day}	VDV_{night}	VDV_{day}	VDV_{night}	
Residential	St Annes' House; The Bungalow	n/a	40	40	8	0.8	0.4	0.8	0.4	125
Commercial Buildings	Frylite	n/a	45	45	8	1.6	n/a	1.6	n/a	125
Existing Utilities	All along alignment	n/a	n/a	n/a	50	50mm/s PPV				All along alignment

14.3.1.4 Sensitive Receptors AZ4 Northwood to Charlemont

There are many sensitive receptors in the vicinity of the route in AZ4 that include multiple residential dwellings, schools, buildings of architectural merit, healthcare facilities and places of business that contain electronic equipment. Examples of representative receptors in the area of AZ4 and in the vicinity of the proposed Project are shown in Table 14.18 together with the applicable noise and vibration assessment thresholds.

Table 14.18: Assessment Locations and Thresholds for AZ4 Northwood to Charlemont

Building / Location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration					Air overpressure (blasting)
					Blasting mm/s PPV	Construction/ TBM $ms^{-1.75}$		Operation $ms^{-1.75}$		
		TBM Passage	Mechanical Excavation	Operation		VDV_{day}	VDV_{night}	VDV_{day}	VDV_{night}	
Residential	Albert College	45	40	40	8	0.8/ 1	0.4/	0.8	0.4	125

Building / Location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration					Air overpressure (blasting)
					Blasting mm/s PPV	Construction/ TBM ms$^{-1.75}$		Operation ms$^{-1.75}$		
		TBM Passage	Mechanical Excavation	Operation		VDV_{day}	VDV_{night}	VDV_{day}	VDV_{night}	
	Court; Dalcasian Downs; Cross Gun Quay Apartments; Berkeley Road; O'Connell Street; Earlsfort Terrace; Harcourt Terrace; Dartmouth Square West						0.5			
Education	Scoil an Tseachtar Laoch & Our Lady of Victories Girl's School	45	40	40	8	1.6	n/a	0.4	n/a	125
Church	St Joseph's Church; Our Lady of Victories.	40	35	35	3	1.6	n/a	0.4	n/a	125
Healthcare	Rotunda Hospital; Dublin Dental University Hospital;	45	40	40	8	0.2/ 0.4	0.1/ 0.2	0.2	0.1	125
	Mater Hospital	45	40	40	8	VC-E		VC-E		125
Trinity College Buildings	Chemistry Extension Building; Sami Nasr Institute; Moyne Institute	45	40	40	8	VC-E		VC-E		125
Museum	National Museum; National Gallery; Natural History Museum	45	40	40	3	VC-A		VC-A		125
Library	National Library	45	40	40	8	1.6	n/a	0.8	n/a	125
Theatre	Gate Theatre; Abbey	30	25	25	8	0.8/ 1	n/a	0.8	n/a	125

Building / Location Description	Locations	Groundborne noise level, $L_{Amax,S}$ dB			Vibration					Air overpressure (blasting)
					Blasting mm/s PPV	Construction/ TBM $ms^{-1.75}$		Operation $ms^{-1.75}$		
		TBM Passage	Mechanical Excavation	Operation		VDV_{day}	VDV_{night}	VDV_{day}	VDV_{night}	
	Theatre; National Concert Hall									
Hotel	Jury's Inn, The Shelbourne;	45	40	40	8	0.8/ 1	0.4/ 0.5	0.2	0.4	125
Office	Dublin Bus Office; General Post Office; The Irish Times; Dublin Fire Brigade HQ; Leinster House; Office of Public Works; new Charlemont oversite development	45	40	40	8	1.6	n/a	0.8	n/a	125
Structures	Parnell Monument; Moore Street National Monument	n/a	n/a	n/a	15	15mm/s PPV		15mm/s PPV		125
Heritage Building	42 O'Connell Street	n/a	n/a	n/a	3	0.8/ 1	n/a	0.8	n/a	125
Existing Utilities	All along alignment	n/a	n/a	n/a	50	50mm/s PPV		50mm/s PPV		n/a

14.3.2 Baseline Surveys

Given the limited existence and extent of vibration in the baseline environment, vibration and groundborne noise can be disregarded in all areas more than 50m from an existing line on the intercity, DART or Luas lines. This distance is based on professional experience of other railway schemes where in general vibration is insignificant at distances greater than 25m from an at-grade railway. Within that distance it is relevant to consider locations where there is an existing impact due to vibration or groundborne noise from the operation of a rail system. However, the assessment methodology does not take pre-existing groundborne noise into account.

14.3.2.1 Baseline Vibration Survey

The baseline vibration environment has been characterised through vibration surveys in areas where potential vibration sources form part of the baseline environment. This has been limited to representative survey locations in the vicinity of existing rail lines adjacent to the proposed Project.

Baseline vibration surveys have been conducted at locations representative of the nearest sensitive areas which have the potential to be impacted by construction works and/or those likely to be impacted during the Operational Phase, which currently are exposed to sources of vibration. These are shown in Table 14.19 below.

Baseline vibration measurements were carried out for a period of five to seven days at each location using logging monitoring equipment. A total of total of three locations have been monitored which sit within AZ4. There are no baseline vibration monitoring positions within AZ1 to AZ3 due to the absence of any significant baseline vibration levels in the surrounding environment of these zones.

Full details of survey locations, methodologies, parameter definitions and results of the baseline surveys are included in Appendices A13.3 to A13.5. Figure 14.1 presents the baseline vibration monitoring locations.

Baseline vibration surveys were carried out at the locations listed in Table 14.19.

Table 14.19: Vibration Baseline Monitoring Locations

Location	Description of Survey Location	Survey Dates
VM01	Coke Oven Cottages, Glasnevin. South of Dublin to Maynooth Railway Line, approximately 20m from nearside rail line.	16th to 23rd May 2019
VM02	O'Connell Street, to rear of Dr. Quirkey's façade to west of Luas Cross City rail line. Measurement position was approximately 25m from nearside rail line	25th June to 2nd July 2019
VM03	Charlemont, within development site to east of Luas Green Line embankment. Measurement position was approximately 2m from base of rail embankment and approximately 4m below rail line.	3rd to 8th May 2019

The vibration survey results are summarised in Table 14.20 below, in terms of VDV.

Table 14.20: Vibration Baseline Monitoring Results Summary

Location	Daytime (07:00-23:00hrs)			Night-time (23:00 – 07:00hrs)		
	$VDV_{,b,\ day}$ $(m/s^{-1.75})$	Typical train pass by VDV_b $(m/s^{-1.75})$	Baseline, VDV_b $(m/s^{-1.75})$	$VDV_{,b,\ night}$ $(m/s^{-1.75})$	Typical train pass by VDV_b $(m/s^{-1.75})$	Baseline VDV_b $(m/s^{-1.75})$
VM01	0.03 – 0.05	0.002 – 0.01	0.0003	0.011 – 0.015	0.002 -0.01	0.0003
VM02	0.006 – 0.03	0.001 – 0.0015	0.0003	0.004 – 0.005	0.001 – 0.0015	0.0003
VM03	0.008 – 0.014	0.001-0.002	0.0004	0.005 – 0.012	0.001 – 0.002	0.0004

14.3.2.2 Vibration Surveys at TCD Buildings

Of particular importance is the case of highly sensitive equipment, for example in hospital laboratories or treatment facilities such as linear accelerators. Apart from the potential for cumulative effects, the existence of vibration in the baseline may mean that mitigation has already been incorporated in the installations so that there is significant attenuation of vibration reaching the equipment thus reducing the potential effect of added vibration sources in the future.

Vibration assessment criteria are normally based on absolute values and the baseline would only be taken into account where there is likely to be vibration from more than one source in combination. The receptors to which this applies are the laboratories at TCD, and baseline surveys were carried out in the areas listed in Table 14.21, with the associated sensitive equipment. Full details of survey locations, methodologies, parameter definitions and results of the baseline surveys at TCD are included in Appendix A13.5.

Table 14.21: Trinity College Dublin Buildings and Equipment

Building	Equipment
Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN) Building. Room 2.32 and Room 2.33	Scanning Tunnelling Microscopes

Building	Equipment
Chemistry Extension Building	Nuclear Magnetic Resonance laboratory
Fitzgerald Building, room 0.1	Scanning Tunnelling Microscopes
Fitzgerald Building, room 1.5	Alternating Grade Field Magnometer
Monck Observatory	solar/optical telescope and a radio telescope located on roof of building
Sami Nasr Institute of Advanced Materials (SNIAM) Building	Superconducting quantum interference device (SQUID) High speed camera laboratory
Panoz Building	Scanning Electron Microscopes
Lloyd Institute	MRI machine

One of the purposes of the survey was to discover the degree of vibration isolation which is provided by the foundations of the instruments surveyed. The surveys findings are discussed in the following subsections.

14.3.2.2.1 CRANN building Scanning Tunnelling Microscopes – Room 2.32

This room is located in the lower basement of the CRANN building, two floors below ground level, and contained two Scanning Tunnelling Microscopes on vibration isolation mounts on bespoke inertia blocks.

- Near the instrument base, on the inertia block adjacent to one of the instruments, the overall maximum acceleration 0.4Hz-31.5Hz was not more than $0.0114m/s^2$ in any axis; and 1Hz – 100Hz was not more than $0.0123m/s^2$;
- Near the instrument base, on the inertia block adjacent to one of the instruments, the overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0804mm/s in any axis; and 1Hz – 100Hz was not more than 0.0813mm/s; and
- Measurements 1.7m away from the base on the tiled floor shows that some 10dB of attenuation occurs between the structural floor and the instrument base in the horizontal axis with the highest amplitudes, but in the vertical axis the attenuation was much less at around 2dB.

14.3.2.2.2 CRANN building Scanning Tunnelling Microscopes – Room 2.33

This room is located on the second floor of the CRANN building and contained two Scanning Tunnelling Microscopes.

- Near the instrument base the overall maximum acceleration 0.4Hz-31.5Hz was not more than $0.0134m/s^2$ in any axis; and 1Hz – 100Hz was not more than $0.0174m/s^2$;
- Near the instrument base the overall maximum velocity 0.4Hz-31.5Hz was not more than 0.1015mm/s in any axis; and 1Hz – 100Hz was not more than 0.1032mm/s; and
- Measurements away from the base show that some little attenuation occurs between the structural floor and the instrument base.

14.3.2.2.3 Chemistry Building Nuclear Magnetic Resonance laboratory

Two rooms located in the basement of the Chemistry building extension contain three Nuclear Magnetic Resonance instruments. The rooms were isolated from the adjoining corridor.

- The overall maximum acceleration 0.4Hz-31.5Hz was not more than $0.0014m/s^2$ in any axis; and 1Hz – 100Hz was not more than $0.0067m/s^2$; and
- The overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0151mm/s in any axis; and 1Hz – 100Hz was not more than 0.0151mm/s.

14.3.2.2.4 Fitzgerald building Scanning Tunnelling Microscopes Room 0.1

This room is located on the ground floor of the Fitzgerald Building and the sensitive equipment in the room included a Scanning Tunnelling Microscope.

- Near the instrument base the overall maximum acceleration 0.4Hz-31.5Hz was not more than 0.0044m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0045m/s^2;
- Near the instrument base the overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0323mm/s in any axis; and 1Hz-100Hz was not more than 0.0323mm/s; and
- Measurements away from the base show that little attenuation occurs between the structural floor and the instrument base.

14.3.2.2.5 Fitzgerald building Alternating Grade Field Magnometer Room 1.5

This room is located on the first floor of the Fitzgerald Building and the sensitive equipment in the room included an Alternating Gradient Field Magnometer.

- Near the instrument base the overall maximum acceleration 0.4Hz-31.5Hz was not more than 0.0044m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0111m/s^2; and
- Near the instrument base the overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0319mm/s in any axis; and 1Hz-100Hz was not more than 0.0375mm/s.

14.3.2.2.6 Monck Observatory

The Monck Observatory is located on the roof of the Fitzgerald Building, the sensitive equipment on the roof included a solar/optical telescope and a radio telescope.

- The overall maximum acceleration 0.4Hz-31.5Hz was not more than 0.055m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0686m/s^2; and
- The overall maximum velocity 0.4Hz-31.5 Hz was not more than 0.6536mm/s in any axis; and Hz-100Hz was not more than 0.6572mm/s.

14.3.2.2.7 SNIAM building SQUID 0.16

This room is located on the ground floor of the SNIAM Building and the sensitive equipment in the room included a Semiconducting Quantum Interference Device.

- The overall maximum acceleration near to the base of the Semiconducting Quantum Interference Device 0.4Hz-31.5Hz was not more than 0.0032m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0042m/s^2; and
- The overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0256mm/s in any axis; and 1Hz-100Hz was not more than 0.0248mm/s.

14.3.2.2.8 SNIAM building high speed camera laboratory

This room is located in the basement of the SNIAM Building and the sensitive equipment in the room included a high-speed camera.

- The overall maximum acceleration near to the base of the Semiconducting Quantum Interference Device 0.4Hz-31.5Hz was not more than 0.0021m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0025m/s^2; and
- The overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0185mm/s in any axis; and 1Hz-100Hz was not more than 0.0185mm/s.

14.3.2.2.9 Panoz building Scanning Electron Microscopes

These rooms are located in the basement of the Panoz building and the sensitive equipment included Scanning Electron Microscopes.

- The overall maximum acceleration near to the base of the Scanning Electron Microscopes (SEM) 0.4Hz-31.5Hz was not more than 0.0004m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0009m/s^2;
- The overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0076mm/s in any axis; and 1Hz-100Hz was not more than 0.0049mm/s; and
- Measurements 2m away from the base show that little attenuation occurs between the structural floor and the instrument base.

14.3.2.2.10 Lloyd Institute MRI machine

This room is located in the basement of the Lloyd Institute, the sensitive equipment included a Magnetic Resonance Imaging machine. The room was isolated from the adjoining corridor and the control room.

- The overall maximum acceleration near to the base of the MRI machine 0.4Hz-31.5Hz was not more than 0.0028m/s^2 in any axis; and 1Hz-100Hz was not more than 0.0033m/s^2; and
- The overall maximum velocity 0.4Hz-31.5Hz was not more than 0.0245mm/s in any axis; and 1Hz-100Hz was not more than 0.0241mm/s.

14.3.2.3 Baseline Noise Measurements

With regard to receptors with high sensitivity to groundborne noise, while the significance criteria are couched in absolute terms it is informative to place these in the context of existing conditions. Internal noise surveys were carried out in the National Concert Hall and the Gate Theatre, as these buildings are considered to be sensitive.

The report containing a summary of the noise monitoring equipment, monitoring locations and baseline monitoring results at the National Concert Hall and Gate Theatre is provided in Appendix A13.4.

14.3.2.3.1 National Concert Hall

Baseline noise measurements were undertaken within the Auditorium of the National Concert Hall. This room is located towards the rear of the building, on the ground floor, and is isolated from the foyer by a corridor.

The baseline survey of internal noise levels found that baseline noise levels, in terms of $L_{Aeq, 15 min}$, were typically in the range of 22dB - 24dB and levels of L_{AFmax} were in the range 38dB-54dB, consistent with an auditorium of this kind.

14.3.2.3.2 Gate Theatre

Measurements were undertaken in the rehearsal room and Auditorium. The rehearsal room is located on level two of the Gate Theatre building, with the ventilation system in operation for some of the measurements. The Auditorium is located on level two of the building.

The baseline survey of internal noise levels found that baseline noise levels, in terms of $L_{Aeq, 15 min}$, were in the range of 27dB – 33dB and L_{AFmax} 49dB – 63dB, consistent with an auditorium of this kind. In the rehearsal room the results were slightly higher, in the range of 26dB – 43dB and L_{AFmax} 43dB – 77dB.

Extensive investigation and assessment were undertaken for the preparation of the Environmental Impact Statement for the Metro North scheme in 2008. Much of the currently proposed alignment, particularly towards the northern end of the scheme, is similar to the previous alignment, therefore some of the previously gathered information is of use for the current proposed design. This pre-existing information has been supplemented by a review of all currently available desktop study information particularly in areas where the currently proposed route deviates from the previous scheme.

14.4 Predicted Impacts

14.4.1 Construction Phase Impacts

Potential Impacts during the Construction Phase arising from groundborne noise and vibration could arise from the following activities:

- Progress of the TBM;
- Drilling and Blasting used for station excavation; and
- Mechanical excavation used for station excavation and excavation of the cut, cut and cover sections including diaphragm walling.

Vibration and groundborne noise from the operation of the TBM has been predicted and is presented as contours of groundborne noise (Refer to Figure 14.2). Groundborne noise is the principal effect with regard to residential receptors, as vibration will be below the threshold of significance. Vibration becomes a potential effect with regard to sensitive equipment in hospitals and research laboratories, and the prediction for these cases are presented as spot predictions rather than as contours in assessment tables below. The alignment is in tunnel in sections AZ2 and AZ4.

Blasting and mechanical excavation will be used for station construction and contours of peak particle velocity (ppv) have been generated to indicate the distances at which criteria in ppv are reached. (Refer to Figure 14.3 for Mechanical Excavation, Figures 14.4 and 14.5 for Blasting contours and)

14.4.1.1 Section AZ1 Northern Section

The tunnel boring machine will not be utilised in the construction of this section of the alignment and blasting is not proposed for any excavation along this alignment. The construction of this element of the proposed Project will be by way of mechanical excavation, that includes secant piling, where one of the closest buildings to this activity would be the Woodies homeware store just north of Seatown roundabout on the R132.

Calculations of vibration from secant piling at a distance of 2.7m from Woodies indicate that the highest level of vibrations during construction would be approximately 1.2mm/s, reducing by about half into the building. A vibration level of 0.6mm/s entering the building would, even if continuous through the VDV_{day} 16-hour period (which is not likely), be equivalent to a VDV well below the threshold level for significant effects on "occupants of residential buildings" of $0.8ms^{-1.75}$ (Table 14.11). This is not a residential building, with residential buildings at greater distances and therefore below the threshold level for significant impact for all such receptors in AZ1. The calculated level of vibration is well below the threshold level for building damage (Table 14.8).

As no significant impacts are predicted for the Woodies building to this activity within the geographical area of AZ1, there are not predicted to be any significant impacts for any other buildings within AZ1.

14.4.1.2 Section AZ2 Airport Section

With the TBM in the limestone, groundborne noise levels are predicted to be approximately 50dB(A) over the crown of the TBM where there is 13m of ground cover above the tunnel, decreasing at the rate of approximately 0.5dB per metre reduction in ground cover. Figure 14.2 indicates predicted groundborne noise during TBM passage;

- 25m to the side of the tunnel in the limestone there is a reduction of 5dB(A), with a trend showing a reduction of 0.3dB(A) per metre beyond that distance; and
- 20m ahead of and behind the tunnel face in the limestone there is a reduction of 3dB(A), with a trend showing a reduction of 0.3dB(A) per metre beyond that distance.

Vibration is predicted to be below the VC-A curve, and thus there would be no significant vibration effect on equipment at the airport.

14.4.1.3 AZ2 – Groundborne Noise during Construction

Potential sources of groundborne noise during the Construction Phase are the passage of the TBM and mechanical excavation. Contours of groundborne noise are presented in Figure 14.2 for TBM passage and Figure 14.3 for mechanical excavation. Table 14.22 present the predictions of groundborne noise for a selection of receptors in the geographical area of AZ2.

Table 14.22: Predicted Groundborne Noise during TBM Passage at Receptors in AZ2

Receptor	TBM Passage, LAmax,s dB			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	40	44	Significant	Noticeable to all and disturbing to some over a number of days
Dublin Airport, central head office	45	45	Significant	Noticeable to all and disturbing to some over a number of days
Dublin Airport, Terminal 1 building	45	48	Significant	Noticeable to all and disturbing to some over a number of days

The threshold for groundborne noise during the passage of the TBM is predicted to be exceeded at four receptors in the area of AZ2 that includes the Terminal 1 multi story car park as well as the receptors listed n Table 14.21. A full list of predictions for buildings within 50m of the TBM passage is presented in Appendix A14.5.

Table 14.23: Predicted Groundborne Noise during Mechanical Excavation at Receptors in AZ2

Receptor	Mechanical Excavation, $L_{Amax,s}$ dB			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	35	34	Not significant	No significant Impact
Dublin Airport, central head office	40	36	Not significant	No significant Impact
Dublin Airport, Terminal 1 building	40	28	Not significant	No significant Impact

There are no predicted exceedances of the threshold levels during mechanical excavation at any receptor within the geographical area of AZ2. A full list of predictions for buildings within 50m of the mechanical excavation is presented in Appendix A14.5.

The modelling indicates that the predicted vibration levels from the advancement of the TBM and mechanical excavation within AZ2 will not exceed threshold values that would result in impacts to any utilities in the area.

14.4.1.4 AZ2 – Groundborne Vibration during Construction

Potential sources of groundborne vibration during the Construction Phase are the passage of the TBM and mechanical excavation. Calculations of groundborne vibration during the Construction Phase are presented in Table 14.24 and Table 14.25 against thresholds for human response.

Table 14.24: Predicted Vibration during TBM Passage at Receptors in AZ2

Receptor	TBM Passage, VDV_{day} $ms^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	1.6	0.194	Not significant	No significant Impact
Dublin Airport, central head office	1.6	0.208	Not significant	No significant Impact
Dublin Airport, Terminal 1 building	1.6	0.249	Not significant	No significant Impact

There are no predicted exceedances of the vibration thresholds for human response during TBM passage in the geographical area of AZ2. A full list of predictions for buildings within 50m of the TBM passage is presented in Appendix A14.5.

Table 14.25: Predicted Vibration during Mechanical Excavation at Receptors in AZ2

Receptor	Mechanical Excavation, VDV_{day} $ms^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	1.6	0.002	Not significant	No significant Impact
Dublin Airport, central head office	1.6	0.002	Not significant	No significant Impact
Dublin Airport, Terminal 1 building	1.6	0.001	Not significant	No significant Impact

There are no exceedances of the vibration thresholds for human response during mechanical excavation in the geographical area of AZ2.

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8. Vibration is predicted to be below the VC-A curve, and thus there would be no significant vibration effect on equipment at the airport. Appendix A14.5 presents a full list of predictions for buildings within 50m of mechanical excavation.

14.4.1.5 AZ2 – Blasting

Blasting is proposed to be used for excavation at underground station locations. This would result in the generation of groundborne noise, vibration and air overpressure emissions during blast events contours of peak particle velocity (ppv) and air overpressure have been generated and are presented in Figures 14.4 and 14.5 respectively. Predictions for receptors in AZ2 are given in Table 14.26 and Table 14.27. For air overpressure the contours presented in Figure 14.5 represent blasts carried out with 'average burial' confinement whereas the predictions given in Table 14.26 indicate levels where blasts are 'highly confined'.

Table 14.26: Predicted Vibration Levels during Blasting at Receptors in AZ2

Receptor	Blasting Vibration, PPV			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	3	3.5	Significant	Potential for structural impacts

Receptor	Blasting Vibration, PPV			
	Threshold Level	Predicted Level	Impact	Description of Impact
Dublin Airport, central head office	8	4.6	Not significant	No significant impact
Dublin Airport, Terminal 1 building	8	1.2	Not significant	No significant impact

In the geographic area of AZ2 there is predicted to be an exceedance of the threshold for vibration at Our Lady Queen of Heaven Church during blasting.

Table 14.27: Predicted Air Overpressure during Blasting at Receptors in AZ2

Receptor	Blasting Air Overpressure			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady Queen of Heaven Church	125	106.6	Not significant	No significant Impact
Dublin Airport, central head office	125	108.2	Not significant	No significant Impact
Dublin Airport, Terminal 1 building	125	99.8	Not significant	No significant Impact

There are no exceedances of air overpressure thresholds for significant impacts when blasts are 'highly confined'.

14.4.1.6 Section AZ3 Dardistown to Northwood

The tunnel boring machine will not be utilised in the construction of this section of the alignment and blasting is not proposed for any excavation along this alignment. The construction of this element of the proposed Project will be by way of mechanical excavation, that includes secant piling at Dardistown Station.

Calculations of vibration from secant piling at a distance of 2.7m from the Woodies building (in the AZ1 area) indicates that the highest level of vibrations during construction would be approximately 1.2mm/s, reducing by about half into the building. A vibration level of 0.3mm/s entering the building would be below the threshold level for human disturbance (Refer to Table 14.6) and well below the threshold levels for building damage (Refer to Table 14.8). As there are no buildings closer to the alignment through the AZ3 area than the Hertz building at 5.8m there will be no impacts on buildings arising from the construction activity here.

The noise and vibration generation during the construction of the Depot site is assessed in Chapter 13 (Airborne Noise & Vibration) as there are no sensitive locations in close enough proximity to the depot location as to be subjected to groundborne noise and vibration.

14.4.1.7 Section AZ4 Northwood to Charlemont

The city tunnel portal is at Northwood Station, and the tunnel would enter the limestone about 200m beyond the portal with L_{ASmax} of over 50dB at buildings above. Receptors within approximately 75m of the tunnel centreline are predicted to experience significant groundborne noise for a period of up to two weeks as the TBM passes.

The tunnel would remain in the limestone through Collins Avenue and Griffith Park Stations with the predicted value of L_{ASmax} slightly below 50dB. Receptors within approximately 65m of the tunnel centreline will experience significant groundborne noise for a period of up to two weeks as the TBM passes.

Just north of Glasnevin Station the tunnel would rise into the boulder clay, but although the source strength is less due to the softer structure of the soil compared to the limestone, vibration is reflected off the rockhead below, with the result that there would be little overall reduction in levels of groundborne noise at ground level. With the TBM in the boulder clay, groundborne noise levels are likely to be 44dB(A) over the crown of the TBM in cases where there is 20m of ground cover above the tunnel. For every 1m decrease in ground cover, the groundborne noise levels at the crown of the TBM increase at the rate of approximately 0.5dB(A); 25m to the side of the tunnel in the boulder clay there is a reduction of 3dB(A), with a trend showing a reduction of 0.15dB(A) per metre beyond that distance; 20m ahead of and behind the tunnel face in the boulder clay there is a reduction of 3dB(A), with a trend showing a reduction of 0.2 to 0.3dB(A) per metre.

A short distance to the south of the proposed Mater Station, the base of the tunnel enters the limestone and by O'Connell Street Station it is fully in the limestone. Receptors within approximately 65m of the tunnel centreline will experience significant groundborne noise for a period of up to two weeks as the TBM passes.

The contours of groundborne noise during TBM passage (Figure 14.2) remain a similar width for the remainder of the tunnel between O'Connell St and Charlemont.

With regard to vibration effects on sensitive equipment, Criterion VC-E will occur within a distance of 250m either side of the tunnel centreline, and during the passage of the TBM there is a potential significant effect on the operation of sensitive equipment.

14.4.1.8 AZ4 – Groundborne Noise during Construction

Table 14.28 presents predictions of groundborne noise during TBM passage for a cross section of receptors in the geographical area of AZ4. The values presented are applicable for both day and night-time working hours as there is no separate threshold for works being undertaken at night, such as TBM passage or mechanical excavation in the area of Glasnevin Station.

Table 14.28: Predicted Groundborne Noise during TBM Passage at Residential Receptors in AZ4

Receptor	TBM Passage, $L_{Amax,s}$ dB				
	Threshold Level	Predicted Level	Magnitude	Impact	Description of Impact
Albert College Court	45	48		High Adverse (significant)	Noticeable to all and disturbing to some over a number of days
Dalcasian Downs	45	49		High Adverse (significant)	Noticeable to all and disturbing to some over a number of days
Cross Gun Quay Apartments	45	49		High Adverse (significant)	Noticeable to all and disturbing to some over a number of days
Berkeley Road	45	49		High Adverse (significant)	Noticeable to all and disturbing to some over a number of days
O'Connell Street	45	50	Very High Adverse	Significant	Noticeable to all and disturbing to some over a number of days
35 Pearse Street	45	50	Very High Adverse	Significant	Noticeable to all and disturbing to some over a number of days

Receptor	TBM Passage, $L_{Amax,s}$ dB				
	Threshold Level	Predicted Level	Magnitude	Impact	Description of Impact
Trinity College, Dixon Hall	45	49	High Adverse	Significant	Noticeable to all and disturbing to some over a number of days
20 Earlsfort Terrace	45	50	Very High Adverse	Significant	Noticeable to all and disturbing to some over a number of days
9 Harcourt Terrace	45	49	High Adverse	Significant	Noticeable to all and disturbing to some over a number of days
Dartmouth Square West	45	49	High Adverse	Significant	Noticeable to all and disturbing to some over a number of days

Table 14.29: Predicted Groundborne Noise during TBM Passage at Non-Residential Receptors in AZ4

Receptor	TBM Passage, $L_{Amax,s}$ dB			
	Threshold Level	Predicted Level	Impact	Description of Impact
Scoil an Tseachtar Laoch	45	50	Significant	Noticeable to all and disturbing to some over a number of days
Our Lady of Victories Girl's School	45	43	Not significant	No significant Impact
Our Lady of Victories	40	45	Significant	Noticeable to all and disturbing to some over a number of days
Mater Hospital	45	48	Significant	Noticeable to all and disturbing to some over a number of days
St Joseph's Church	40	49	Significant	Noticeable to all and disturbing to some over a number of days
Gate Theatre	30	49	Significant	Noticeable to all and disturbing to some during quiet performances
Rotunda Hospital	45	49	Significant	Noticeable to all and disturbing to some over a number of days
Jurys Inn	45	43	Not significant	No significant Impact
Dublin Bus Office	45	49	Significant	Noticeable to all and disturbing to some over a number of days
General Post Office	45	50	Significant	Noticeable to all and disturbing to some over a number of days
Abbey Theatre	30	45	Significant	Noticeable to all and disturbing to some during quiet performances.
The Irish Times	45	46	Significant	Noticeable to all and disturbing to some over a number of days
Dublin Fire Brigade HQ	45	50	Significant	Noticeable to all and disturbing to some over a number of days
Trinity College, Chemistry Building	45	47	Significant	Noticeable to all and disturbing to some over a number of days
Trinity College, Sami Nasr Institute	45	49	Significant	Noticeable to all and disturbing to some over a number of days

Receptor	TBM Passage, $L_{Amax,s}$ dB			
	Threshold Level	Predicted Level	Impact	Description of Impact
Dublin Dental University Hospital	45	44	Not Significant	No predicted impact
Trinity College, Moyne Institute	45	48	Significant	Noticeable to all and disturbing to some over a number of days
Trinity Point	45	48	Significant	Noticeable to all and disturbing to some over a number of days
National Museum	45	48	Significant	Noticeable to all and disturbing to some
National Gallery	45	44	Not Significant	No predicted impact
National Library	45	48	Significant	Noticeable to all and disturbing to some
Leinster House	45	49	Significant	Noticeable to all and disturbing to some over a number of days
The Shelbourne	45	47	Significant	Noticeable to all and disturbing to some
Office of Public Works	45	50	Significant	Noticeable to all and disturbing to some over a number of days
National Concert Hall	30	49	Significant	Noticeable to all and disturbing to some during quiet performances.
Charlemont station new oversite development	45	49	Significant	Noticeable to all and disturbing to some over a number of days

During the passage of the TBM there are exceedances of groundborne noise at all buildings within 65m-75m of the tunnel centre, depending on the ground material the TBM is passing through.

Table 14.30: Predicted Groundborne Noise during Mechanical Excavation at Residential Receptors in AZ4

Receptor	Mechanical Excavation, $L_{Amax,s}$ dB				
	Threshold Level	Predicted Level	Magnitude	Impact	Description of Impact
Albert College Court	40	36	Low	Not-significant	No significant Impact
Dalcasian Downs	40	40	Medium	Significant	Noticeable to all and disturbing to some over a number of days
Cross Gun Quay Apartments	40	32	Low	Not-significant	No significant Impact
Berkeley Road	40	25	Low	Not-significant	No significant Impact
35 Pearse Street	40	20	Low	Not-significant	No significant Impact
Harcourt Terrace	40	26	Low	Not-significant	No significant Impact
Dartmouth Square West	40	38	Low	Not-significant	No significant Impact

Table 14.31: Predicted Groundborne Noise during Mechanical Excavation at Non-Residential Receptors in AZ4

Receptor	Mechanical Excavation, $L_{Amax,s}$ dB			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady of Victories Girl's School	40	27	Not significant	No significant Impact
Our Lady of Victories	35	33	Not significant	No significant Impact
Mater Hospital	40	33	Not significant	No significant Impact
St Joseph's Church	35	35	Significant	Noticeable
Gate Theatre	25	19	Not significant	No significant Impact
Rotunda Hospital	40	24	Not significant	No significant Impact
Jurys Inn	40	30	Not significant	No significant Impact
Dublin Bus Office	40	35	Not significant	No significant Impact
General Post Office	40	21	Not significant	No significant Impact
The Irish Times	40	36	Not significant	No significant Impact
Dublin Fire Brigade HQ	40	40	Significant	Noticeable
Leinster House	40	16	Not significant	No significant Impact
The Shelbourne	40	26	Not significant	No significant Impact
Office of Public Works	40	27	Not significant	No significant Impact
Charlemont station new oversite development	40	42	Significant	Noticeable to all and disturbing to some over a number of days

There are a small number of predicted exceedances of the groundborne noise thresholds during mechanical excavation. These are in the area of Dartmouth Square West, Glasvevin Station, Tara Station and Charlemont Station.

14.4.1.9 AZ4 – Groundborne Vibration during Construction

Calculations of groundborne vibration during the Construction Phase are presented in Table 14.32 for TBM passage and Table 14.33 for mechanical excavation.

Table 14.32: Predicted Vibration during TBM Passage at Receptors in AZ4

Receptor	TBM Passage							
	VDV_{day} $ms^{-1.75}$ / VC-A – E (where applicable)				VDV_{night} $ms^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impact	Threshold Level	Predicted Level	Impact	Description of Impact
Scoil an Tseachtar Laoch	1.6	0.271	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Our Lady of Victories Girl's School	1.6	0.179	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Our Lady of Victories	1.6	0.206	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Albert College Court	1	0.242	Not Significant	No significant Impact	0.5	0.203	Not Significant	No significant Impact

Receptor	TBM Passage							
	VDV$_{day}$ ms$^{-1.75}$ / VC-A – E (where applicable)				VDV$_{night}$ ms$^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impact	Threshold Level	Predicted Level	Impact	Description of Impact
Dalcasian Downs	1	0.263	Not Significant	No significant Impact	0.5	0.221	Not Significant	No significant Impact
Cross Gun Quay Apartments	1	0.265	Not Significant	No significant Impact	0.5	0.223	Not Significant	No significant Impact
Berkeley Road	1	0.259	Not Significant	No significant Impact	0.5	0.281	Not Significant	No significant Impact
Mater Hospital	0.4	00.249	Not Significant	No significant impact	0.2	0.21	Significant	Noticeable to all and disturbing to some over a number of days
St Joseph's Church	1.6	00.265	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Gate Theatre	1	00.26	Not Significant	No significant impact	n/a	n/a	n/a	n/a
Rotunda Hospital	0.4	00.261	Not Significant	No significant Impact	0.2	0.22	Significant	Noticeable to all and disturbing to some over a number of days
12/13 O'Connell Street	1	0.273	Not Significant	No significant Impact	0.5	0.229	Not Significant	No significant Impact
42 O'Connell Street	1	0.272	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Jurys Inn	1	0.18	Not Significant	No significant Impact	0.5	0.151	Not Significant	No significant Impact
Dublin Bus Office	1.6	0.267	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
General Post Office	1.6	0.269	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Abbey Theatre	1	0.217	Not Significant	No significant impact	n/a	n/a	n/a	n/a
The Irish Times	1.6	0.21	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Dublin Fire Brigade HQ	1.6	0.269	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
35 Pearse Street	1	0.270	Not Significant	No significant Impact	0.5	0.227	Not Significant	No significant Impact

Receptor	TBM Passage							
	VDV_{day} $ms^{-1.75}$ / VC-A – E (where applicable)				VDV_{night} $ms^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impact	Threshold Level	Predicted Level	Impact	Description of Impact
Trinity College, Dixon Hall	1	0.257	Not Significant	No significant Impact	0.5	0.216	Not Significant	No significant Impact
Trinity College, Chemistry Building	VC-E	>VC-A	Significant	Disturbance to sensitive equipment	n/a	n/a	n/a	n/a
Trinity College, Sami Nasr Institute	VC-E	>VC-A	Significant	Disturbance to sensitive equipment	n/a	n/a	n/a	n/a
Dublin Dental University Hospital	0.4	0.274	Not Significant	No significant Impact	0.2	0.162	Not Significant	No significant Impact
Trinity College, Moyne Institute	VC-E	VC-A	Significant	Disturbance to sensitive equipment	n/a	n/a	n/a	n/a
Trinity Point	1	0.248	Not Significant	No significant impact	0.5	0.208	Not Significant	No significant impact
National Museum	VC-A	>VC-A	Not Significant	No significant impact	n/a	n/a	n/a	n/a
National Gallery	VC-A	>VC-A	Not Significant	No significant impact	n/a	n/a	n/a	n/a
National Library	1.6	0.235	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
Leinster House	1.6	0.253	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
The Shelbourne	1	0.232	Not Significant	No significant Impact	0.5	0.196	Not Significant	No significant Impact
Office of Public Works	1.6	0.275	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
National Concert Hall	1	0.255	Not Significant	No significant Impact	n/a	n/a	n/a	n/a
20 Earlsfort Terrace	1	0.274	Not Significant	No significant Impact	0.5	0.231	Not Significant	No significant Impact
9 Harcourt Terrace	1	0.262	Not Significant	No significant Impact	0.5	0.221	Not Significant	No significant Impact
Dartmouth Square West	1	0.254	Not Significant	No significant Impact	0.5	0.214	Not Significant	No significant Impact
Charlemont station new oversite development	1.6	0.265	Not Significant	No significant impact	n/a	n/a	n/a	n/a

During the passage of the TBM there are exceedances of vibration thresholds at some buildings close to the passage of the TBM. Some parts of the Hospital buildings at night-time and also TCD buildings are predicted to exceed their threshold for significant effects.

Table 14.33: Predicted Vibration during Construction Mechanical Excavation at receptors in AZ4

Receptor	Mechanical Excavation, VDV_{day} $ms^{-1.75}$			
	Threshold Level	Predicted Level	Impact	Description of Impacts
Our Lady of Victories Girl's School	1.6	0.001	Not significant	No significant Impact
Our Lady of Victories	1.6	0.001	Not significant	No significant Impact
Albert College Court	0.8	0.002	Not significant	No significant Impact
Berkeley Road	0.8	0.001	Not significant	No significant Impact
Mater Hospital	0.2	0.001	Not significant	No significant Impact
St Joseph's Church	1.6	0.002	Not significant	No significant Impact
Gate Theatre	1.6	0	Not significant	No significant Impact
Rotunda Hospital	0.2	0.001	Not significant	No significant Impact
42 O'Connell Street	0.8	0.002	Not significant	No significant Impact
Jurys Inn	0.8	0.001	Not significant	No significant Impact
Dublin Bus Office	1.6	0.002	Not significant	No significant Impact
General Post Office	1.6	0	Not significant	No significant Impact
The Irish Times	1.6	0.002	Not significant	No significant Impact
Dublin Fire Brigade HQ	1.6	0.003	Not significant	No significant Impact
Leinster House	1.6	0	Not significant	No significant Impact
The Shelbourne	0.8	0.001	Not significant	No significant Impact
Office of Public Works	1.6	0.001	Not significant	No significant Impact
9 Harcourt Terrace	0.8	0.001	Not significant	No significant impact
Dartmouth Square West	0.8	0.002	Not significant	No significant Impact
Charlemont station new oversite development	1.6	0.004	Not significant	No significant impact

There are no predicted exceedances of vibration thresholds during mechanical excavation.

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8.

14.4.1.10 AZ4 – Blasting

Blasting is proposed to be used for excavation at underground station locations. This would result in the generation of groundborne noise, vibration and air overpressure emissions during blast events contours of peak particle velocity (ppv) and air overpressure have been generated and are presented in Figures 14.4 and 14.5 respectively. Predictions for a cross section of receptors within proximity of blasting activity in AZ4 are given in Table 14.34 and Table 14.35. For air overpressure the contours presented in Figure 14.5 represent blasts carried out with 'average burial' confinement whereas the predictions given in Table 14.31 indicate levels where blasts are 'highly confined'.

Table 14.34: Predicted Blasting Vibration Levels at Receptors in AZ4

Receptor	Blasting Vibration, PPV			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady of Victories Girl's School	8	1.2	Not significant	No significant Impact
Our Lady of Victories	3	2.7	Not significant	No significant Impact
Albert College Court	8	4.3	Not significant	No significant Impact
Berkeley Road	8	0.8	Not significant	No significant Impact
Mater Hospital	8	3.1	Not significant	No significant Impact
St Joseph's Church	3	4.2	Significant	Above threshold for significant impact on structures for a potentially vulnerable building.
Rotunda Hospital	8	0.7	Not significant	No significant Impact
42 O'Connell Street	3	4	Significant	Above threshold for significant impact on structures for a potentially vulnerable building.
Jurys Inn	8	1.8	Not significant	No significant Impact
Dublin Bus Office	8	4.1	Not significant	No significant Impact
The Irish Times	8	4.3	Not significant	No significant Impact
Dublin Fire Brigade HQ	8	8.1	Significant	Blasting would be noticeable to people within the building, and just above threshold for structures.
The Shelbourne	8	1.0	Not significant	No significant Impact
Office of Public Works	8	1.1	Not significant	No significant Impact
9 Harcourt Terrace	8	0.9	Not significant	No significant Impact
Dartmouth Square West	8	6.1	Not significant	No significant Impact
Charlemont station new oversite development	8	10.7	Significant	Blasting would be noticeable to people within the building, and above the threshold for structures.

The thresholds for vibration during blasting are exceeded at four locations. The threshold for Churches is 3mm/s PPV, which is exceeded with a predicted vibration level of 4.2mm/s PPV at St Joseph's Church. The threshold for 42 O'Connell Street is 3mm/s PPV as a sensitive heritage building with a plaster ceiling, which is exceeded with a predicted vibration level of 4.0mm/s PPV. The threshold of 8mm/s PPV is also predicted to be exceeded at Dublin Fire Brigade HQ and also within the new oversite development at Charlemont station.

Although the threshold of 3PPV is not predicted to be exceeded at Our Lady of Victories Church the predicted level of 2.7PPV is close to the threshold. As a sensitive building mitigation from blasting is considered appropriate for this receptor.

The Townsend Sewer is in close proximity to the station box at Tara Street. The assessment has shown that of the potential sources of vibration in the vicinity of the Townsend Street sewer, namely the excavation and construction of the diaphragm wall, blasting in the rock for the excavation of the station box, the passage of the tunnel boring machine and operation of Metrolink trains, only in the case of blasting it there a clear risk that the damage threshold might be reached. It will be necessary to begin blasting at the part of the station box most distant from the sewer and through monitoring of blasts as the distance is reduced either to reduce maximum instantaneous charge weights or cease blasting and use less impactful means of excavation and hence eliminate any potential impacts on the sewer.

No other utilities are close enough to the site to allow impact criteria be exceeded as set out in Section 14.2.1.2.1. As a result, there are no potential impacts on utilities identified.

Table 14.35: Predicted Blasting Air Overpressure Levels at Receptors in AZ4

Receptor	Blasting Air Overpressure			
	Threshold Level	Predicted Level	Impact	Description of Impact
Our Lady of Victories Girl's School	125	99.6	Not significant	No significant Impact
Our Lady of Victories	125	104.8	Not significant	No significant Impact
Albert College Court	125	107.8	Not significant	No significant Impact
Berkeley Road	125	97	Not significant	No significant Impact
Mater Hospital	125	105.6	Not significant	No significant Impact
St Joseph's Church	125	107.6	Not significant	No significant Impact
Rotunda Hospital	125	96.3	Not significant	No significant Impact
42 O'Connell Street	125	107.3	Not significant	No significant Impact
Jurys Inn	125	102.2	Not significant	No significant Impact
Dublin Bus Office	125	107.6	Not significant	No significant Impact
The Irish Times	125	107.8	Not significant	No significant Impact
Dublin Fire Brigade HQ	125	111.9	Not significant	No significant Impact
The Shelbourne	125	98.2	Not significant	No significant Impact
Office of Public Works	125	99.1	Not significant	No significant Impact
9 Harcourt Terrace	125	97.8	Not significant	No significant Impact
Dartmouth Square West	125	110.1	Not significant	No significant Impact
Charlemont station new oversite development	125	113.7	Not significant	No significant impact

There are no predicted exceedances of air overpressure at any receptor during blasting in the geographical area of AZ4 when blasts are undertaken in highly confined conditions.

14.4.2 Operational Phase Impacts

Potential Impacts during the operation phase arising from groundborne noise and vibration could arise from the rolling stock using the tracks and tunnels.

Contours of groundborne noise have been prepared which indicate that significance criteria for groundborne noise in residential buildings, churches, courts, lecture theatres, small auditoria/halls, schools, colleges, libraries offices and commercial buildings would be exceeded in very few cases, based on the assumptions made for the system-wide trackform as set out in Appendix A14.3.

There is the potential for significant vibration effects in the case of laboratories housing scientific equipment of high sensitivity. Because of the sensitivity of equipment at very low frequencies, and the fact that mitigation for the purpose of minimising groundborne noise does not reduce, or may increase, low frequency vibration, there is a risk that manufacturers' criteria for sensitive equipment at TCD could be exceeded.

However, based on current assumptions the assessment shows that criteria for sensitive equipment at TCD can be satisfied but during the procurement stage care will be needed to ensure that the track support systems ultimately selected are capable of achieving an equivalent result.

This section presents the results of the assessment of potential operational groundborne noise and vibration impacts in the geographical area of AZ1, where the sources assessed are groundborne noise and vibration from the operational railway.

14.4.2.1.1 AZ1 - Groundborne Noise from Railway Operation

Contours of operational groundborne noise are presented in Figure 14.6, the contours indicate a groundborne noise contour of 40dB $L_{Amax,s}$ at an approximate distance of 16m from the track centre, with 35dB $L_{Amax,s}$ occurring at approximately 27m from the centre of the track.

There is a total of eight residential buildings five office/commercial/retail premises within AZ1 where the 40dB $L_{Amax,s}$ threshold is predicted to be exceeded. There are no exceedances of the 35dB $L_{Amax,s}$ threshold level at any churches in AZ1. Table 14.36 provides examples of calculated results at representative residential receptors and Table 14.37 results for all receptors in AZ1 are presented in Appendix 14.5.

Table 14.36: Predicted Groundborne Noise during Railway Operation at Residential Receptors in AZ1

Receptor	Threshold Groundborne Noise $L_{Amax,s}$ dB	Predicted Groundborne Noise $L_{Amax,s}$ dB	Impact	Description of Impact
Estuary Court	40	37	Low (not significant)	No significant impact
Ashley Avenue	40	38	Low (not significant)	No significant impact
Seaview Mews	40	42	Medium Adverse (significant)	Noticeable to all and disturbing to some.
Veterinary Clinic	40	41	Medium Adverse (significant)	Noticeable to all and disturbing to some.
Fingal House Nursing Home	40	25	Low (not significant)	No significant impact

There are two residential receptors where the groundborne noise threshold is predicted to be exceeded during the operation of the railway in the geographical area of AZ1.

Table 14.37: Predicted Groundborne Noise during Railway Operation at Non-Residential Receptors in AZ1

Receptor	Threshold Groundborne Noise $L_{Amax,s}$ dB	Predicted Groundborne Noise $L_{Amax,s}$ dB	Impact	Description of Impact
O'Scanaill Veterinary Hospital	40	37	Not significant	No significant impact
Hertz Customer Services Centre	40	36	Not significant	No significant impact
Fujitsu Ireland	40	38	Not significant	No significant impact
Tara Winthrop Private Clinic	40	21	Not significant	No significant impact
Woodies DIY	45	46	Significant	Noticeable to all and disturbing to some.

14.4.2.1.2 AZ1 – Groundborne Vibration from Railway Operation

Calculations of groundborne vibration during the construction at example receptors phase are presented in Table 14.38 and considered against the thresholds given in Table 14.9 for significant effects on building occupants.

Table 14.38: Predicted Groundborne Vibration during Railway Operation at Receptors in AZ1

Receptor	Day Vibration, VDV_{day} $mms^{-1.75}$			Night Vibration, VDV_{night} $mms^{-1.75}$			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
Estuary Court	0.009	None	Adverse comment not expected	0.004	None	Adverse comment not expected	Not Significant
Ashley Avenue	0.010	None	Adverse comment not expected	0.005	None	Adverse comment not expected	Not Significant
Seaview Mews	0.013	None	Adverse comment not expected	0.006	None	Adverse comment not expected	Not Significant
Veterinary Clinic	0.012	None	Adverse comment not expected	0.006	None	Adverse comment not expected	Not Significant
Fingal Nursing Home	0.003	None	Adverse comment not expected	0.001	None	Adverse comment not expected	Not Significant
O'Scanaill Veterinary Hospital	0.009	None	Adverse comment not expected	n/a	None	Adverse comment not expected	Not Significant
Hertz Customer Services Centre	0.007	None	Adverse comment not expected	n/a	None	Adverse comment not expected	Not Significant
Fujitsu Ireland	0.009	None	Adverse comment not expected	n/a	None	Adverse comment not expected	Not Significant
Tara Winthrop Private Clinic	0.002	None	Adverse comment not expected	0.001	None	Adverse comment not expected	Not Significant

Receptor	Day Vibration, VDV_{day} $mms^{-1.75}$			Night Vibration, VDV_{night} $mms^{-1.75}$			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
Woodies DIY	0.020	None	Adverse comment not expected	n/a	None	Adverse comment not expected	Not Significant

There are no significant impacts for vibration from railway operation in the geographical area of AZ1.

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8.

14.4.2.2 Section AZ2 Airport Section

This section presents the results of the assessment of potential groundborne noise and vibration impacts in the geographical area of AZ2, where the sources assessed are groundborne noise and vibration from the operation phase.

Vibration from track maintenance in the airport tunnel will be substantially below criteria for vibration effects on equipment at the airport.

14.4.2.3 AZ2 – Groundborne Noise from Railway Operation

Contours of operational groundborne noise are presented in Figure 14.6, the contours indicate a groundborne noise contour of 40dB $L_{Amax,s}$ at an approximate distance of 16m from the track centre, with 35dB $L_{Amax,s}$ occurring at approximately 27m from the centre of the track.

There are no receptors within AZ2 where the groundborne noise threshold is predicted to be exceeded.

Table 14.39: Predicted Groundborne Noise during Railway Operation at Receptors in AZ2

Receptor	Groundborne Noise $L_{Amax,s}$ dB		Impact	Description of Potential Impact
	Threshold Level	Predicted Level		
Our Lady Queen of Heaven Church	35	18	Negligible (Not significant)	No significant Impact
Dublin Airport, central head office	40	22	Negligible (Not significant)	No significant Impact
Dublin Airport, Terminal 1 building	40	33	Negligible (Not significant)	No significant Impact

There are no predicted exceedances for groundborne noise thresholds for the operation of the railway in the geographical area of AZ2.

14.4.2.4 AZ2 – Groundborne Vibration from Railway Operation

The threshold of a significant impact from groundborne vibration during operation of the metro is $0.2ms^{-1.75}$ $VDV_{b,day}$. Calculations of groundborne vibration during the Construction Phase are presented in Table 14.40.

Table 14.40: Predicted Groundborne Vibration during Railway Operation at Receptors in AZ2

Receptor	Vibration, VDV_{day} $mms^{-1.75}$	Magnitude	Effect	Impact
	Predicted Level			

Our Lady Queen of Heaven Church	0.002	None	Adverse comment not expected	Not Significant
Dublin Airport, central head office	0.002	None	Adverse comment not expected	Not Significant
Dublin Airport, Terminal 1 building	0.006	None	Adverse comment not expected	Not Significant

There are no predicted significant impacts for vibration from railway operation in the geographical area of AZ2.

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8.

14.4.2.5 Section AZ3 Dardistown to Northwood

This section presents the results of the assessment of potential groundborne noise and vibration impacts in the geographical area of AZ3, where the sources assessed are groundborne noise and vibration from the operational railway.

14.4.2.5.1 AZ3 – Groundborne Noise from Railway Operation.

Contours of groundborne noise are presented in Figure 14.6, the contours indicate a groundborne noise contour of 40dB $L_{Amax,s}$ at an approximate distance of 16m from the track centre. There are no buildings within AZ3 where 40dB $L_{Amax,s}$ is predicted to be exceeded.

Table 14.41: Predicted Groundborne Noise during Railway Operation at Receptors in AZ3

Receptor	Groundborne Noise $L_{Amax,s}$ dB		Impact	Description of Potential Impact
	Threshold Level	Predicted Level		
St Anne's House	40	11	Low (Not significant)	No significant Impact
The Bungalow	40	15	Low (Not significant)	No significant Impact
Frylite	45	25	Not significant	No significant Impact

There are no predicted exceedances of the groundborne noise threshold at any receptor in the geographical area of AZ3 during operation of the railway.

14.4.2.5.2 AZ3 – Groundborne Vibration from Railway Operation

Calculations of groundborne vibration during the operation phase are presented in Table 14.42.

Table 14.42: Predicted Groundborne Vibration during Railway Operation at Receptors in AZ3

Receptor	Daytime Vibration, VDV_{day} $mms^{-1.75}$			Night time Vibration, VDV_{night} $mms^{-1.75}$			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
St Anne's House	0.001	None	Adverse comment not expected	0.000	None	Adverse comment not expected	Not significant
The Bungalow	0.001	None	Adverse comment not expected	0.001	None	Adverse comment not expected	Not significant Impact
Frylite	0.002	None	Adverse comment not	n/a	n/a	n/a	No Impact

Receptor	Daytime Vibration, VDV_{day} $mms^{-1.75}$			Night time Vibration, VDV_{night} $mms^{-1.75}$			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
			expected				

There are no predicted significant impacts for vibration from railway operation in the geographical area of AZ3.

14.4.2.6 Section AZ4 Northwood to Charlemont

This section presents the results of the assessment of potential groundborne noise and vibration impacts in the geographical area of AZ4, where the sources assessed are groundborne noise and vibration from the operational railway.

14.4.2.6.1 AZ4 - Groundborne Noise from Railway Operation

The threshold of a significant impact from groundborne noise for receptors in AZ4 is 40dB $L_{Amax,s}$. Contours of groundborne noise are presented in Figure 14.6, the contours indicate a groundborne noise contour of 40dB $L_{Amax,s}$ at an approximate distance of 16m from the track centre.

Table 14.43: Predicted Groundborne Noise during Railway Operation at Residential Receptors in AZ4

Receptor	Groundborne Noise $L_{Amax,s}$ dB		Magnitude	Impact	Description of Potential Impact
	Threshold Level	Predicted Level			
Albert College Court	40	29	Low	Not significant	No significant Impact
Dalcasian Downs	40	31	Low	Not significant	No significant Impact
Cross Gun Quay Apartments	40	33	Low	Not significant	No significant Impact
Berkeley Road	40	33	Low	Not significant	No significant Impact
12/13 O'Connell Street	40	36	Low	Not significant	No significant Impact
35 Pearse Street	40	35	Low	Not significant	No significant Impact
Trinity, Dixon Hall	40	35	Low	Not significant	No significant Impact
Dartmouth Square West	40	21	Low	Not significant	No significant Impact

There are no exceedances predicted of the groundborne noise threshold for residential receptors in the geographical area of AZ4.

Table 14.44: Predicted Groundborne Noise during Railway Operation at Buildings in AZ4

Receptor	Groundborne Noise $L_{Amax,s}$ dB		Impact	Description of Potential Impact
	Threshold Level	Predicted Level		
Scoil an Tseachtar Laoch	40	36	Not significant	No significant Impact
Our Lady of Victories	40	17	Not significant	No significant Impact

Receptor	Groundborne Noise $L_{Amax,s}$ dB		Impact	Description of Potential Impact
	Threshold Level	Predicted Level		
Girl's School				
Our Lady of Victories	35	19	Not significant	No significant Impact
Mater Hospital	40	29	Not significant	No significant Impact
St Joseph's Church	35	33	Not significant	No significant Impact
Gate Theatre	25	34	Significant	Noticeable to all and disturbing to some during quiet performances
Rotunda Hospital	40	33	Not significant	No significant Impact
Jurys Inn (Parnell St)	40	14	Not significant	No significant Impact
Dublin Bus Office	40	32	Not significant	No significant Impact
General Post Office	40	35	Not significant	No significant Impact
Abbey Theatre	25	27	Significant	Noticeable to all and disturbing to some during quiet performances
The Irish Times	40	19	Not significant	No significant Impact
Dublin Fire Brigade HQ	40	33	Not significant	No significant Impact
Trinity College, Chemistry Building	40	30	Not significant	No significant Impact
Trinity College, Sami Nasr Institute	40	35	Not significant	No significant Impact
Dublin Dental University Hospital	40	23	Not significant	No significant Impact
Trinity, Moyne Institute	40	34	Not significant	No significant Impact
Trinity Point	40	32	Not significant	No significant Impact
National Museum	40	32	Not significant	No significant Impact
National Gallery	40	21	Not significant	No significant Impact
National Library	40	32	Not significant	No significant Impact
Leinster House	40	34	Not significant	No significant Impact
The Shelbourne	40	28	Not significant	No significant Impact
Office of Public Works	40	35	Not significant	No significant Impact
National Concert Hall	25	34	Significant	Noticeable to all and disturbing to some during quiet performances
20 Earlsfort Terrace	40	37	Not significant	No significant Impact
9 Harcourt Terrace	40	30	Not significant	No significant Impact
Charlemont station new oversite development	40	29	Not significant	No significant impact

There are two predicted exceedances of the groundborne noise threshold at two Theatres in the geographical area of AZ4 during operation of the railway, with no other predicted exceedances.

14.4.2.6.2 AZ4 – Groundborne Vibration from Railway Operation

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8.Section AZ4 Northwood to Charlemont. Calculations of groundborne vibration during the Operational Phase are presented in Table 14.45.

Table 14.45: Predicted Groundborne Vibration during Railway Operation for building occupants at Receptors in AZ4

Receptor	Day Vibration, VDVday mms-1.75			Night Vibration, VDVnight mms-1.75			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
Scoil an Tseachtar Laoch	0.010	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Our Lady of Victories Girl's School	0.002	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Our Lady of Victories	0.002	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Albert College Court	0.005	None	Adverse comment not expected	0.003	None	Adverse comment not expected	Not significant
Dalcasian Downs	0.006	None	Adverse comment not expected	0.003	None	Adverse comment not expected	Not significant
Cross Gun Quay Apartments	0.007	None	Adverse comment not expected	0.004	None	Adverse comment not expected	Not significant
Berkeley Road	0.007	None	Adverse comment not expected	0.004	None	Adverse comment not expected	Not significant
Mater Hospital	0.005	None	Adverse comment not expected	0.023	None	Adverse comment not expected	Not significant
St Joseph's Church	0.006	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Gate Theatre	0.008	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Rotunda Hospital	0.008	None	Adverse comment not expected	0.033	None	Adverse comment not expected	Not significant
12/13 O'Connell Street	0.010	None	Adverse comment not expected	0.005	None	Adverse comment not expected	Not significant
42 O'Connell Street	0.007	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Jurys Inn	0.001	None	Adverse comment not	0.001	None	Adverse comment not	Not significant

Receptor	Day Vibration, VDVday mms-1.75			Night Vibration, VDVnight mms-1.75			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
			expected			expected	
Dublin Bus Office	0.007	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
General Post Office	0.009	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Abbey Theatre	0.004	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
The Irish Times	0.002	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Dublin Fire Brigade HQ	0.008	None	Adverse comment not expected	n/a	n/a	n/a	No significant Impact
35 Pearse Street	0.009	None	Adverse comment not expected	0.005	None	Adverse comment not expected	Not significant
Trinity, Dixon Hall	0.009	None	Adverse comment not expected	0.005	None	Adverse comment not expected	Not significant
Dublin Dental University Hospital	0.010	None	Adverse comment not expected	0.006	None	Adverse comment not expected	Not significant
Trinity Point	0.007	None	Adverse comment not expected	0.004	None	Adverse comment not expected	Not significant
National Library	0.007	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
Leinster House	0.008	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
The Shelbourne	0.005	None	Adverse comment not expected	0.003	None	Adverse comment not expected	Not significant
Office of Public Works	0.009	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
National Concert Hall	0.008	None	Adverse comment not expected	n/a	n/a	n/a	Not significant
20 Earlsfort Terrace	0.11	None	Adverse comment not expected	0.006	None	Adverse comment not expected	Not significant
9 Harcourt	0.006	None	Adverse	0.003	None	Adverse	Not

Receptor	Day Vibration, VDVday mms-1.75			Night Vibration, VDVnight mms-1.75			Impact
	Predicted Level	Magnitude	Effect	Predicted Level	Magnitude	Effect	
Terrace			comment not expected			comment not expected	significant
Dartmouth Square West	0.002	None	Adverse comment not expected	0.001	None	Adverse comment not expected	Not significant
Charlemont station new oversite development	0.005	None	Adverse comment not expected	n/a	n/a	n/a	n/a

There are no predicted significant impacts for vibration from railway operation in the geographical area of AZ4.

Table 14.46: Predicted Groundborne Vibration during Railway Operation for buildings containing sensitive equipment in AZ4

Receptor	Day Vibration, VDV_{day} $mms^{-1.75}$			Description of potential Impact
	Threshold Level	Predicted Level	Effect	
Trinity College, Chemistry Building	VC-E	VC-A	Significant	Potential Impact on sensitive equipment
Trinity College, Sami Nasr Institute	VC-E	VC-A	Significant	Potential Impact on sensitive equipment
Trinity, Moyne Institute	VC-E	VC-A	Significant	Potential Impact on sensitive equipment
National Museum and National Gallery	VC-A	VC-A	Not Significant	No significant impact

The calculated vibration levels are below the threshold for structural damage for any building type, as presented in Table 14.8.

14.5 Mitigation

14.5.1 Construction Phase

The document *Transport Infrastructure Ireland (TII) Airborne Noise and Ground-borne Noise Mitigation Policy (Appendix A14.6)* sets out the construction noise insulation and temporary rehousing measures to be implemented. This document will be implemented during the Construction Phase of the proposed Project, the key elements of the policy are summarised below.

- **Noise Insulation:** This is the provision of secondary glazing to the windows of affected habitable rooms. Additional ventilation provision might be necessary to allow the windows to be kept closed whilst maintaining the appropriate number of air changes in the room. Secondary glazing increases noise attenuation and this can provide a material improvement to the internal noise environment.
- **Temporary Rehousing:** Where construction noise levels are such that noise insulation will not provide sufficient attenuation to prevent disturbance or interference with activities or sleep, then the occupants can be temporarily re-housed away from the construction site.

14.5.1.1 Tunnel boring

The modelling exercise undertaken to advise the analysis presented in this chapter has identified potential for significant effects resulting from the advancement of the TBM. However, the exceedances identified arising from the advancement of the TBM at any single location will occur for a very short period of days as the TBM passes beneath a location. The precise duration of any exceedances is variable and a function of the spatial extent of a property above the path of the TBM.

Unfortunately, there are no effective methods are available to reduce groundborne noise or vibration from TBMs at source. The principal mitigation measures aimed at minimising impacts are as follows:

- Advance public consultation and stakeholder engagement can greatly reduce the significance of groundborne noise effects, as building occupants would be prepared for the passage of the TBM and resultant elevated noise and vibration levels.
- TII will accept and consider applications for additional measures on a case-by case basis, in accordance with its Noise and Vibration Mitigation Policy (see Appendix A14.6).
- With regard to vibration effects on the use of sensitive equipment, there is potential to plan the passage of the TBM during weeks when critical use of the equipment can be avoided. The programme for the TBM will be planned by the contractor. Consultation will be undertaken with TCD as soon as this programme is available to ensure that sensitive research operations on the campus do not coincide with the passage of the TBM.

14.5.1.2 Blasting

Mitigation measures to reduce the impact of blasting entail the following:

- Prepare a correct blast design based on a survey of the rock face profile prior to design;
- Minimisation of the explosive charge per delay. This could involve the following:

- Reducing the drilling diameter of the hole for explosives.
- Shortening the length of the holes for explosives;
- Initiating charges at different times; and
- Using the maximum number of detonators possible.

- Choose an effective delay time between holes and rows which would avoid wave interaction and give good rock displacement;
- Set the explosive initiation sequence in a way that it progresses away from the structures to be protected;
- Use an adequate powder factor (weight of explosives per volume of excavated material). When the powder factor is lower than what is needed, the increase in charge confinement leads to an increase in intensity of vibrations. Excessive consumption will create an unnecessary overload, accompanied by great disturbing effects;
- Create shields or discontinuities between the structures to be protected and the blasting;
- Monitoring of blasting and re-optimising the blast design considering the results, changing conditions and experience should be carried out as standard;
- Increase confinement of the explosive charges with a long stemming height (more than 25 times the hole diameter, but not excessive) and use adequate, inert material;
- Place barriers between blasting area and sensitive receptors if required;
- Cover the blasting area carefully with a blast mat or similar; and
- Cover the voids and use acoustic sheds, if required.

It should be noted that the impact of air overpressure as an effect of blasting accompanying ground vibration is strongly dependent on the degree of confinement of the blast. In the assessment carried out, "total confinement" as defined in the IEEE Blaster's Handbook 18th edition has been assumed, and that represents the maximum available mitigation for air overpressure.

Notwithstanding the implementation of the above measures, potential significant impacts have been identified at six receptors where preconstruction condition surveys will be undertaken, and any required pre-construction repair work identified and undertaken. The receptors identified in Section 14.4 are listed:

- Our Lady Queen of Heaven Church;
- St Joseph's Church;
- 42 O'Connell Street;
- Dublin Fire Brigade HQ; and
- Charlemont station new oversite development

Should the above-mentioned mitigation measures not result in a significantly reduced noise and vibration levels such that they are still above the criteria set, then alternative non-explosive excavation methods will be used such as the following:

- Use of non-explosive blasting techniques, such as expanding grout or rock sawing; and
- Use of mechanical excavation instead of blasting.

However, avoidance of blasting would mean extended periods of groundborne noise and vibration impact as alternatives such as mechanical excavation would result in protracted effects throughout the working times over a long period. However, the use of expanding grout and sawing as a means of rock breaking may mitigate the effect at the expense of a protracted programme.

14.5.1.3 Mechanical Excavation

Rock excavation by means other than blasting may be carried out using a road header, in which case no mitigation measures other than controls on times of working are available.

During the Construction Phase, where a contractor has no option but to use plant and equipment such as hydraulic breakers or percussive piling rigs, these can be used as a last resort, but only with the prior agreement with the local authority. The contractor would be required to comply with all limits and restrictions required by the local authority to allow the work to proceed.

The amount of rock to be removed using such a machine may be reduced by first breaking the rock using techniques such as expanding grout (in which case the main source of groundborne noise and vibration is drilling holes for the grout) or sawing, which causes relatively low levels of groundborne noise and vibration.

14.5.2 Operational Phase

With regard to all but a limited number of sensitive receptors, no significant effects are predicted during the Operational Phase. There are some locations where an enhanced track support system will be required.

In the case of buildings that are sensitive to groundborne noise, including buildings containing particularly sensitive equipment as well as large auditoria and studios, mitigation in the form of floating slab track will be incorporated into the design to remove any significant effects during the Operational Phase.

With regard to sensitive laboratory equipment, detailed building-specific numerical modelling will be required to establish the likely exceedance of equipment specifications, and to find the optimum specification for the track support system to minimise exceedances. Mitigation at the receptor for specific rooms within sensitive buildings in the form of the installation of base-isolated foundation slabs to support the equipment may also be required. As the specific sensitive equipment in use at TCD is expected to change between the time of this assessment and the opening of the proposed Project close consultation should be undertaken between TII and TCD in relation to the specifically sensitive rooms.

The sections of the tunnel where mitigation in the form of floating slab track, or other track support measures are required are summarised in Table 14.47.

Table 14.47: Location Summary where Track Support Measures will be Required

Location	Receptor(s)	Design Measure	Threshold to be Met
AZ1, Ch. 2+260 to Ch. 2+400	Seaview Mews	Floating Slab Track	40 dB $L_{Amax,s}$
AZ1, Ch. 2+260 to Ch. 2+400	Veterinary Clinic	Floating Slab Track	40 dB $L_{Amax,s}$
AZ4, Ch. 16+400 to Ch. 16+600	Gate Theatre	Floating Slab Track	25 dB $L_{Amax,s}$ VCD-E
AZ4, Ch. 17+000 to Ch. 17+200	Abbey Theatre	Floating Slab Track	25 dB $L_{Amax,s}$ VCD-E
AZ4, Ch. 17+600 to Ch. 17+980	Trinity College Buildings	Floating Slab Track Detailed design measures for specific rooms containing sensitive electronic equipment.	VCD-E
AZ4, Ch. 17+980, Ch. 18+100	National Museums & National Gallery	Floating Slab Track	VCD-E
AZ4, Ch. 18+760, Ch. 18+940	National Concert Hall	Floating Slab Track	25 dB $L_{Amax,s}$ VCD-E

14.6 Residual Significant Effects

14.6.1 Construction Phase

14.6.1.1 Tunnel Boring

There will be effects during the passage of the TBM which can be mitigated by an early stakeholder engagement programme, so that building occupants would be prepared for the passage of the TBM and resultant temporary elevated noise and vibration levels. Nonetheless, in certain circumstances some residents may find the effect intolerable. TII will accept and consider applications for additional measures on a case-by case basis, in accordance with the Airborne Noise and Vibration Mitigation & Groundborne Noise Mitigation Policy (Refer to Appendix A14.6). Table 14.48 and Table 14.49 present a summary of residual impacts at receptors where a significant impact has been identified for the tunnel boring phase.

Table 14.48: Summary of Residual Impacts during Tunnel Boring in AZ2

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Our Lady Queen of Heaven Church	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement.	Significant
Dublin Airport, central head office	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement.	Significant
Dublin Airport, Terminal 1 building	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement.	Significant

For the representative buildings along the AZ2 section, the modelling has indicated that the TBM advancement would result in exceedances of the criteria for groundborne noise at Our Lady of Victories church and Dublin Airport buildings. However, the exceedance of limits are for a very short period of time of less than two weeks. It is not possible to implement mitigation measures that will reduce the level of groundborne noise and vibration. However, the effects of the elevated noise and vibration levels will be managed by way of public consultation and stakeholder engagement throughout the TBM advancement.

Table 14.49: Summary of Residual Impacts during Tunnel Boring in AZ4

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Scoil an Tseachtar Laoch	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Our Lady of Victories	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Albert College Court	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	High Adverse (significant)
Dalcasian Downs	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	High Adverse (significant)
Cross Gun Quay Apartments	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	High Adverse (significant)
Berkley Road	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	High Adverse (significant)
Mater Hospital	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
	Vibration (human response)	Temporary	Significant (night-time only)	Advance public consultation and stakeholder engagement	Significant (night-time only)
St Joseph's Church	Groundborne Noise	Temporary	Very High Adverse (significant)	Advance public consultation and stakeholder engagement	Very High Adverse (significant)

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Gate Theatre	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Rotunda Hospital	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
	Vibration (human response)	Temporary	Significant (night-time only)	Advance public consultation and stakeholder engagement	Significant (night-time only)
O'Connell Street	Groundborne Noise	Temporary	Very High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	Very High Adverse (significant)
Dublin Bus Office	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
General Post Office	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Abbey Theatre	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
The Irish Times	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Dublin Fire Brigade HQ	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
35 Pearse Street	Groundborne Noise	Temporary	Very High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	Very High Adverse (significant)
Trinity College, Dixon Hall	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation where eligibility has been established.	High Adverse (significant)
Trinity College, Chemistry Building	Groundborne Noise	Temporary	Significant	Noticeable to all and disturbing to some during quiet periods.	Significant
	Vibration	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Trinity College, Sami Nasr Institute	Groundborne Noise	Temporary	Significant	Noticeable to all and disturbing to some during quiet periods.	Significant
	Vibration	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Trinity College,	Groundborne	Temporary	Significant	Advance public consultation	Significant

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Moyne Institute	Noise			and stakeholder engagement	
	Vibration (human response)	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Trinity Point	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
National Museum	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
National Library	Groundborne Noise	Temporary	Very High Adverse (significant)	Advance public consultation and stakeholder engagement	Very High Adverse (significant)
Leinster House	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
The Shelbourne	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Office of Public Works	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
National Concert Hall	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
	Vibration (human response)	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
20 Earlsfort Terrace	Groundborne Noise	Temporary	Very High Adverse (significant)	Advance public consultation, stakeholder engagement and application of TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	Very High Adverse (significant)
9 Harcourt Terrace	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation Policy where eligibility has been established.	High Adverse (significant)
Dartmouth Square West	Groundborne Noise	Temporary	High Adverse (significant)	Advance public consultation, stakeholder engagement and application of the TII Airborne Noise and Ground-borne Noise Mitigation where eligibility has been established.	High Adverse (significant)
Charlemont station new oversite development	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant
Receptors within 65-75m of the tunnel centreline, depending on	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement	Significant

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
ground material.					

14.6.1.2 Mechanical Excavation

Exceedances of groundborne noise thresholds are predicted to be exceeded at one location in AZ4 as summarise in Table 14.50.

Table 14.50: Summary of Residual impacts during Mechanical Excavation in AZ4

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Charlemont station new oversite development	Groundborne Noise	Temporary	Significant	Advance public consultation and stakeholder engagement, and control of working hours.	Significant

14.6.1.3 Blasting

The blasts will be designed by the specialist contractor to avoid significant effects. In any case where proximity of receptors or sensitivity of receptors is such that significant effects cannot be avoided due to blasting, then alternatives to blasting will be employed.

Table 14.51: Summary of Residual impacts during Blasting in AZ2

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Our Lady Queen of Heaven Church	Blasting Vibration	Temporary	Significant	Minimisation of the maximum instantaneous charge weight. Or alternatives to blasting.	Not significant

Table 14.52: Summary of Residual impacts during Blasting in AZ4

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
St Joseph's Church	Blasting Vibration	Temporary	Significant	Minimisation of the maximum instantaneous charge weight. Or alternatives to blasting. Pre-construction condition surveys and pre-construction repair work where necessary	Not significant
42 O'Connell Street	Blasting Vibration	Temporary	Significant	Minimisation of the maximum instantaneous charge weight. Or alternatives to blasting. Pre-construction condition surveys and pre-construction repair work where necessary	Not significant
Dublin Fire Brigade HQ	Blasting Vibration	Temporary	Significant	Minimisation of the maximum instantaneous charge weight. Or alternatives to blasting. Pre-construction condition	Not significant

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
				surveys and pre-construction repair work where necessary	
Charlemont station new oversite development	Blasting vibration	Temporary	Significant	Minimisation of the maximum instantaneous charge weight. Or alternatives to blasting. Pre-construction condition surveys and pre-construction repair work where necessary	Not significant

14.6.2 Operation

14.6.2.1 Groundborne Noise

There will be no residential significant effects with regard to groundborne noise on the basis of the assumed track support system and installation of enhanced track isolation systems including floating slab track in the vicinity of a small number of locations and highly sensitive receptors, and receptor-focussed mitigation for each item of highly sensitive equipment.

14.6.2.2 Vibration

Only in the case of highly sensitive laboratory equipment is it likely to prove difficult to avoid exceeding manufacturers' specification for ambient vibration, which will necessitate receptor-specific mitigation.

Table 14.53 and Table 14.54 present a summary of residual impacts at receptors where a significant impact has been identified for the operational running of the proposed Project.

Table 14.53: Summary of Residual Impacts during Operation in AZ1

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Seaview Mews	Groundborne Noise	Permanent	Significant	Design of track support system (floating slab track)	Not significant
Veterinary Clinic	Groundborne Noise	Permanent	Significant	Design of track support system (floating slab track)	Not significant

Table 14.54: Summary of Residual Impacts during Operation in AZ4

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
Gate Theatre	Groundborne Noise and Vibration	Permanent	Significant	Design of track support system (floating slab track)	Not significant
Abbey Theatre	Groundborne Noise and Vibration	Permanent	Significant	Design of track support system (floating slab track)	Not significant
Trinity College Buildings	Groundborne Vibration	Permanent	Significant	Design of track support system (floating slab track). Detailed design	Not significant

Receptor	Description of Impact	Nature of Impact	Predicted Impact	Mitigation	Residual Impact
				measures for specific rooms containing sensitive electronic equipment.	
National Museums and National Gallery	Groundborne Vibration	Permanent	Significant	Design of track support system (floating slab track)	Not significant
National Concert Hall	Groundborne Noise and Vibration	Permanent	Significant	Design of track support system (floating slab track)	Not significant

14.7 Glossary of Terms

Term	Description
"A" Weighting	The human ear does not respond uniformly to different frequencies. "A" weighting is commonly used to simulate the frequency response of the ear. It is used in the assessment of risk of damage of hearing due to noise and is usually expressed with a capital A in the unit abbreviation (e.g. Lamax, LAeq) or a capital A in brackets after the dB level (i.e. dB(A)).
Air Overpressure	A pulse of air pressure above and below atmospheric pressure, a result of blasting.
Ambient noise	Ambient noise is the total sound in a certain situation at a given time usually composed of sound from many sources, near and far.
Baseline data	Data used to describe the current conditions of the environment, against which future predictions can be made.
Broadband Noise	Noise whose energy is distributed over a wide section of the audible range.
Continuous vibration	Vibration is continuous when it is uninterrupted for the assessment period.
Decibel	The range of audible sound pressures is approximately 2x10-5 Pascals (pa) to 200Pa. Using decibel (dB) notation presents this range in a more manageable form, 0dB to 140dB.
Diurnal	The diurnal changes in traffic flows is a term used to describe the annual average hourly pattern of traffic flows throughout a 24-hour period.
Effect	Term used to express the consequence of an impact (expressed as the 'significance of effect'), which is determined by correlating the magnitude of the impact to the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria. For example, land clearing during construction results in habitat loss (impact), the effect of which is the significance of the habitat loss on the ecological resource.
Embankment	An earthwork to establish the road foundations (along with cuttings), where material is built up on either side of the road, providing potential for visual screening and noise attenuation.
Free-field	The term "free-field" is used to define noise levels that have been measured or predicted in the absence of any influence of reflections from nearby surfaces, other than the ground. In practice, a noise level is considered to be free-field if it is at a distance greater than 3.5m from any reflecting surface, other than the ground.
Groundborne noise	vibration that propagates through the ground to surrounding buildings where it might result in the vibration of floors, walls and ceilings, which could also be heard as a "low frequency 'rumbling' sound" that is referred to as groundborne noise.
Groundborne vibration	Consists of repetitive waves of vibration that propagate form the source through the ground.
Hz	Hertz, the unit of frequency and equal to one cycle per second
Impact	Change that is caused by an action; for example, land clearing (action) during construction

Term	Description
	which results in habitat loss (impact).
Intermittent vibration	Intermittent vibration is vibration which is perceived in separately identifiable repeated bursts. Its onset can be sudden, or there might be a gradual onset and termination bounding a more sustained event. Bursts may happen several to many times in a day or night period.
$L_{Aeq,15\ min}$	Indicates the annual average noise level for the given 15-minute period
L_{pASmax}	Maximum A-weighted sound level, used to describe groundborne noise
Mitigation	Measures intended to avoid, reduce and, where possible, remedy significant adverse environmental effects.
Operation	The functioning of a project on completion of construction.
Peak particle velocity	The peak vibration level generated from groundborne vibration, measured in mm/s.
Secant Pile	Secant pile walls are formed by constructing intersecting reinforced concrete piles. The secant piles are reinforced with either steel rebar or with steel beams and are constructed by either drilling under mud or augering.
Submicron	being less than a micron in a (specified) measurement
Tunelling	To dig or force a passage underground.
Vibration	Continuous quick, slight shaking movement.
VDV	Vibration Dose Value, based on weighted acceleration and dependent on the number and duration of events.

14.8 Difficulties Encountered

No difficulties were encountered.

14.9 References

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