METROLINK

Integrated Transport. Integrated Life.

A13.3 Baseline Vibration Monitoring Report

BASELINE VIBRATION MONITORING FOR DUBLIN METROLINK EIAR

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EXECUTIVE SUMMARY

Vibration monitoring has been conducted at three locations along the alignment of the Metrolink Project. The assessment is summarised as follows.

<u>Glasnevin/ Whitworth (VM01)</u>

At monitoring location VM01, PPV values for the majority of daytime survey periods measured 0.03mm/s indicating a low vibration environment. Analysis of the data indicates the typical PPV value associated with passing rail is between 0.11 and 0.2mm/s.

The calculated daytime VDV value at VM01 is between 003 to 0.05 $m/s^{1.75}$ over the 7 day monitoring period. The calculated night-time VDV value at this location is between 0.011 and 0.015 $m/s^{1.75}$ over the 7 day monitoring period. Analysis of the data indicates the typical VDV associated with passing rail is of the order of 0.002 to 0.01 $m/s^{1.75}$.

The existing baseline VDV_{day} and VDV_{night} values are below a value where a *low probability of adverse comment* would be expected within a building as defined within BS 6472-1 (2008).

<u>O'Connell Street</u>

At monitoring location VM02, PPV values for the majority of daytime survey periods measured 0.04mm/s indicating a low vibration environment. Analysis of the data indicates the typical PPV value associated with passing rail is between 0.05 and 0.08mm/s.

The calculated daytime VDV values is between 0.006 to 0.03 $m/s^{1.75}$ over the 8 day monitoring period. The calculated night-time VDV value at this location is between 0.004 and 0.005 $m/s^{1.75}$ Analysis of the data indicates the typical VDV associated with passing rail is of the order of 0.001 to 0.0015 $m/s^{1.75}$.

The VDV_{day} and VDV_{night} values are below a value where a *low probability of adverse comment* would be expected within a building as defined within BS 6472-1 (2008).

<u>Charlemont</u>

At monitoring location VM03, PPV values for the majority of daytime survey periods measured 0.03mm/s indicating a low vibration environment. Analysis of the data indicates the typical PPV value associated with passing rail is between 0.05 and 0.12mm/s.

The calculated daytime VDV values is between 0.008 to 0.014 $m/s^{1.75}$ over the 5 day monitoring period. The calculated night-time VDV value at this location is between 0.005 and 0.012 $m/s^{1.75}$ Analysis of the data indicates the typical VDV associated with passing rail is of the order of 0.001 to 0.002 $m/s^{1.75}$.

The VDV_{day} and VDV_{night} values are below a value where a *low probability of adverse comment* would be expected within a building as defined within BS 6472-1 (2008).

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1.0 INTRODUCTION

This report includes the relevant survey details and results associated with baseline vibration monitoring undertaken as part of the Metrolink project. The survey has been undertaken to inform the airborne noise and vibration chapter of the Metrolink EIAR.

Vibration monitoring has been undertaken at three locations across the study area. The survey methodology and results are included within this report.

2.0 SURVEY METHODOLOGY

2.1 Survey Locations

Vibration monitoring was undertaken at three locations within Assessment Zone 4 (AZ4) of the Metrolink study area between Northwood and Charlemont. The locations were chosen to represent sensitive locations adjacent to existing sources of vibration (i.e. existing rail lines). The three locations VM01, VM02 and VM03 are described in the following sections.

2.1.1 Location VM01

This monitoring location was positioned at Coke Oven Cottages, Glasnevin. The monitoring position was located in the rear garden of the property, south of Dublin to Maynooth Railway Line, approximately 20m from nearside rail line.

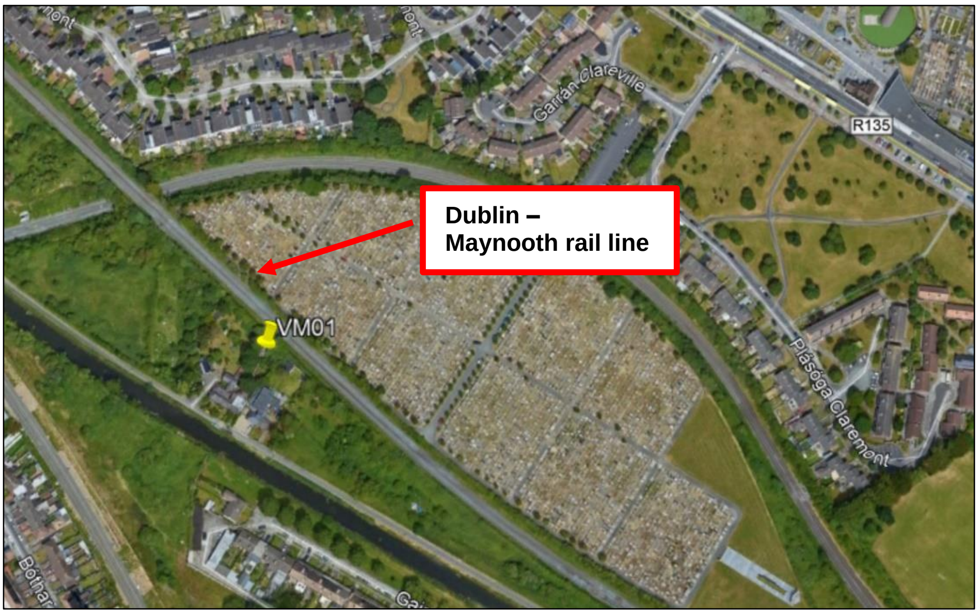

Figure 1 VM01 Monitoring Location

Figure 2 VM01 Equipment Install

2.1.2 Location VM02

This monitoring location was positioned along O'Connell Street, to rear of the temporary scaffold façade adjacent to the Dr. Quirkey's site. The monitoring position was located at ground level at approximately 25m west of the Luas Cross City nearside rail Line.

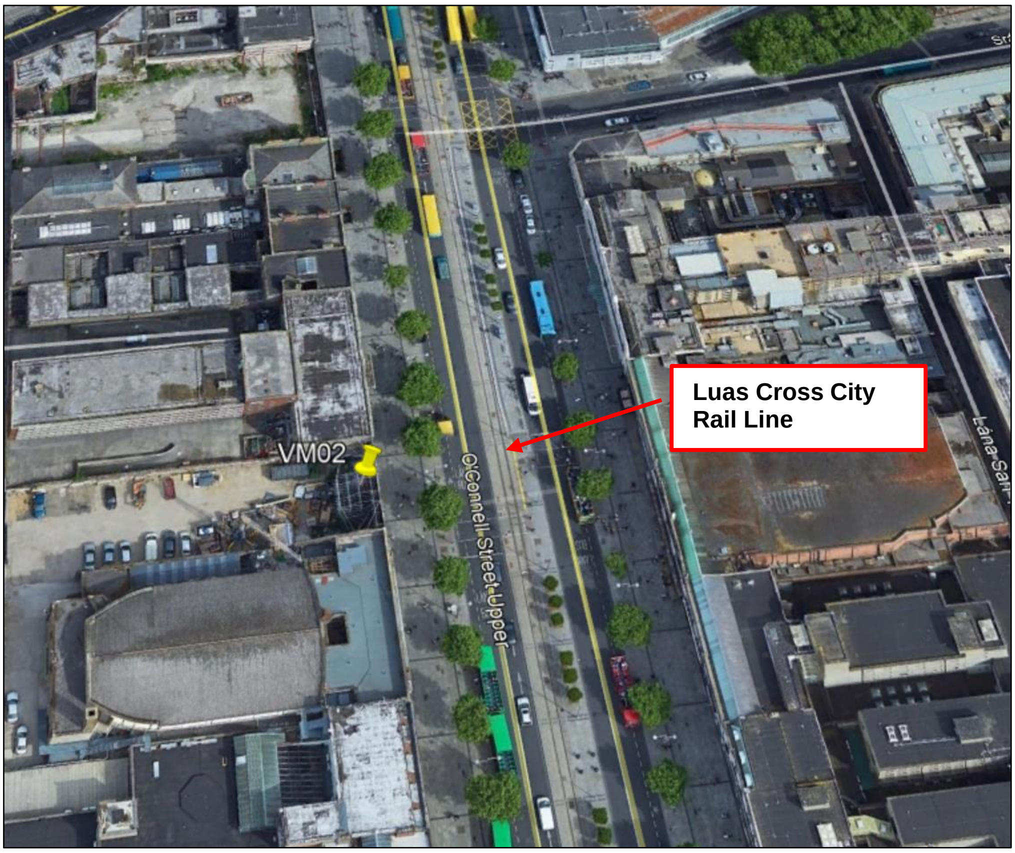

Figure 3 VM02 Monitoring Location

Figure 4 VM02 Equipment Install

2.1.3 Location VM03

This monitoring location was positioned at Charlemont, within a development site to the east of the Luas Green Line, elevated on an embankment. Measurement position was approximately 2m from base of rail embankment and approximately 4m below the rail line.

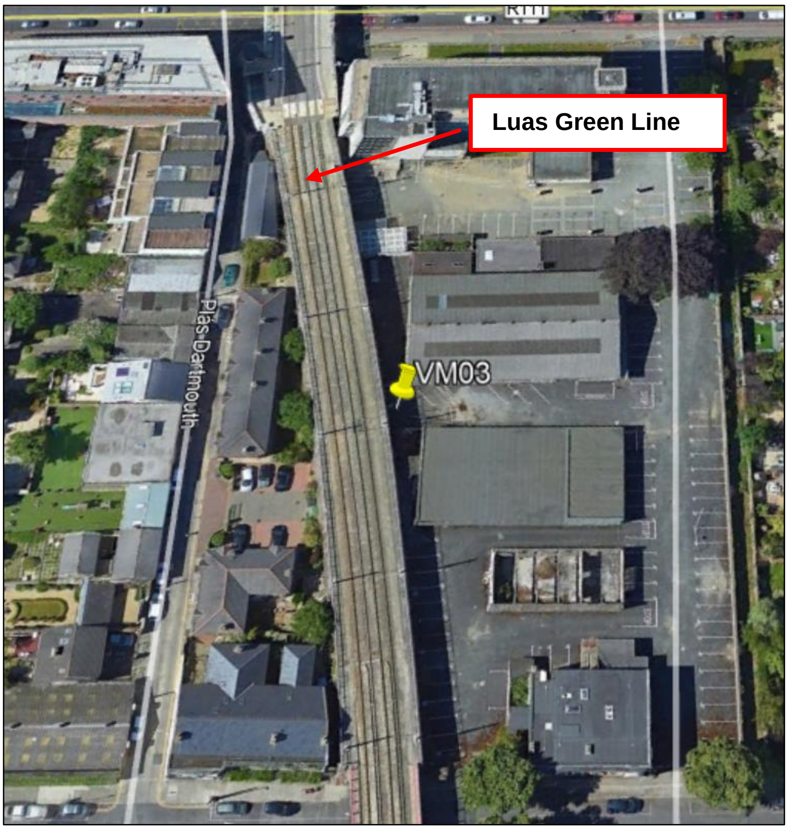

Figure 5 VM03 Monitoring Location

Figure 6 VM03 Equipment Install

2.2 Survey Periods

Vibration monitoring was undertaken over the course of the following periods:

- VM01: 16th May to 23rd May 2019
- VM02: 25th June to 02nd July 2019
- VM03: 03rd May to 08th May 2019

2.3 Survey Equipment and Personnel

The survey was undertaken using a RION VM-56 vibration meter (S/N 680043) with PV-83D tri-axial accelerometer.

Calibration certificate of monitoring equipment are included within Appendix A.

The surveys were conducted by Donal Heavey, acoustic technician (AMIOA), AWN Consulting.

2.4 Survey Procedure

Vibration measurements were conducted in general accordance with the guidance contained in British Standard BS 7385. Part 1*: Guide for measurement of vibrations and evaluation of their effects on buildings* (1990).

Vibration was measured in the three orthogonal axes. The accelerometer was secured in place with a 5kg sandbag at all monitoring locations.

The equipment was set to log for 1 minute intervals on a continual basis at locations VM01 and VM03. A 5 minute interval was set to log at VM02.

2.5 Survey Parameters

The following vibration parameters are discussed within this report.

PPV Peak Particle Velocity (PPV) is a measure of the velocity of vibration displacement in terms of millimetres per second (mm/s). It is defined as follows within BS 7385: (1990) as:

> *"the maximum instantaneous velocity of a particle at a point during a given time interval"*

VDV Vibration Dose Value (VDV) is an evaluation of human exposure to vibration in buildings. It defines a relationship that yields a consistent assessment of continuous, intermittent, occasional and impulsive vibration and correlates well with subjective response. It is defined as follows within British Standard BS 6472: (2008) Guide to evaluation of human exposure to vibration in buildings (2008): Part 1 - Vibration sources other than blasting, as:

"The VDV is the fourth root of the integral of the fourth power of acceleration after it has been frequency-weighted (as defined in BS6472: 2008). The frequency-weighted acceleration is measured in m/s^2 and the time period over which the VDV is measured is in seconds. This yields VDVs in $m/s^{1.75}$"

The frequency weightings used in the BS 6472 (2008) document is W_b weighting for vertical axis and W_d for the horizontal axes.

2.6 Reference Guidance

2.6.1 BS 6472: (2008) Guide to evaluation of human exposure to vibration in buildings (2008): Part 1 - Vibration

The measured baseline VDV are discussed with reference to BS 6472 (2008) Part 1.

BS 6472 uses the Vibration Dose Value (VDV) which is measured or forecast over the day or night-time periods in terms of $m/s^{-1.75}$. The VDV parameter takes into account how people respond to vibration in terms of frequency content, vibration magnitude and the number of vibration events during an assessment period.

The following table, as set out in the standard, details the values of VDV where various comments from occupiers are possible. The standard notes that the values are applicable for both vertical and horizontal vibration with the appropriate weighting applied.

Building Type	Low probability of adverse comment	Adverse comment possible	Adverse comment probable
Residential building – Day	0.2 to 0.4	0.4 to 0.8	0.8 to 1.6
Residential building – Night	0.1 to 0.2	0.2 to 0.4	0.4 to 0.8

Table 1 VDV ($m/s^{-1.75}$) above which various degree of adverse comment may be expected in residential buildings.

2.6.2 BS 5228-2: 2009 + A1 2014: Code of practice for noise and vibration control on construction and open sites – Vibration

There are no current standards which provide guidance on typical ranges of human response to vibration in terms of PPV for continuous or intermittent vibration sources.

BS5228 (2009 + A1 2014) Part 2, provides a useful guide relating to the assessment of human response to vibration in terms of the PPV. Whilst the guide values are used to compare typical human response to construction works, they tend to relate closely to general levels of vibration perception from other general sources. Table 2 below summarises the range of vibration values and the associated potential effects on humans.

Vibration Level, PPV	Effect
0.140 mm/s	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies. At lower frequencies people are less sensitive to vibration.
0.3 mm/s	Vibration might be just perceptible in residential environments.
1 mm/s	It is likely that a vibration level of this magnitude in residential environments will cause complaint.

Table 2 Guidance on effects of human response to PPV magnitudes

3.0 SURVEY RESULTS

3.1 VM01 – Coke Oven Cottages

At Coke Oven Cottages, the accelerometer was positioned within the rear garden of the property at a distance of 20m from the nearside rail (Dublin to Maynooth Railway Line).

On review of the data recorded at this location there are a number of significant outlier vibration values that are associated with the accelerometer being moved/ knocked. The likely source of this is due to the presence of dogs within the garden.

The monitoring data has been reviewed against the Irish rail timetables to align measurement periods against passing train times along the adjacent rail line. Measured vibration values significantly in excess of those associated with train pass bys have been removed as outlier values which do not represent the baseline vibration environment. As noted above these activities are likely due to activities at or adjacent to the accelerometer (e.g. dogs walking nearby, movement of the equipment etc.).

3.1.1 Peak Particle Velocity

Review of train timetables and measurement results confirm measured PPV values are in the range of 0.1 to 0.22mm/s during a train pass by. To account for unknown sources or for potentially heavier laden trains not included in the passenger timetables, monitoring results up to 2mm/s have been included in the baseline data set discussed below.

Table 3 summarises the monitoring results for this location for the horizontal and vertical axes. The range of maximum, minimum and median PPV values recorded over each daytime period (07:00 to 23:00hrs) and each night-time period (23:00 to 07:00hrs) over the 6 day monitoring period are presented. The typical PPV value associated with train pass by's are also included.

Axis	Daytime (07:00-23:00Hhrs)			Night-time (23:00 – 07:00hrs)			Typical train pass by - PPV (mm/s)
	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	
X	1.6 – 2	0.02	0.03	0.26 – 0.8	0.02	0.03	0.08 – 0.2
Y	1.43 – 1.9	0.02	0.03	0.24 – 0.8	0.02	0.03	0.08 – 0.2
Z	0.84 – 1.5	0.02	0.03	0.14 – 0.6	0.02	0.03	0.11 – 0.2

Table 3 PPV values for VM01

Figure 7 presents the distribution of measured PPV values between 0.01 and 2mm/s over the 6 day monitoring periods during daytime hours (07:00 to 23:00hrs) for the vertical axis.

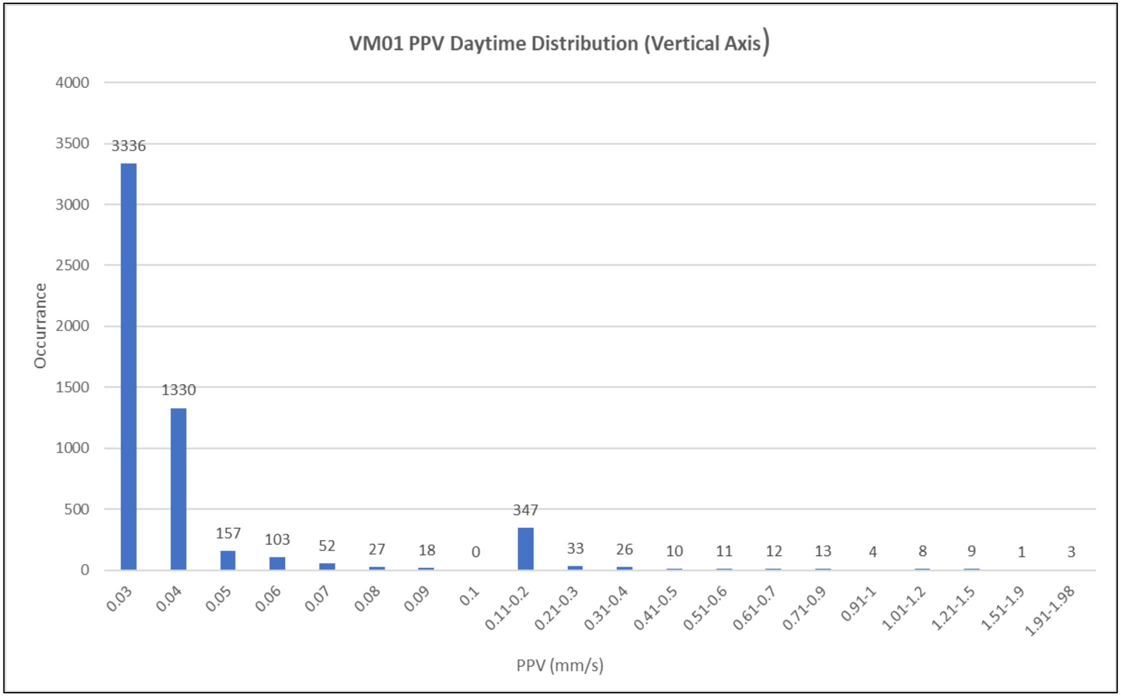

Figure 7 VM01: Daytime PPV Vertical Distribution

PPV values are in the range of 0.03 to 0.09mm/s in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.11 to 0.2mm/s. The dominant frequency associated with a train pass by is in the range of 20 to 40Hz. A low number of PPV events were recorded in the range of 0.2 to 0.9mm/s which are also potentially attributed to rail pass by's. The maximum events recorded are expected to be as a result of activities within the garden, specifically resident's dogs.

Figure 8 presents the distribution of measured PPV values between 0.01 and 2mm/s over the 7 day monitoring periods during night-time hours (23:00 to 07:00hrs) for the vertical axis.

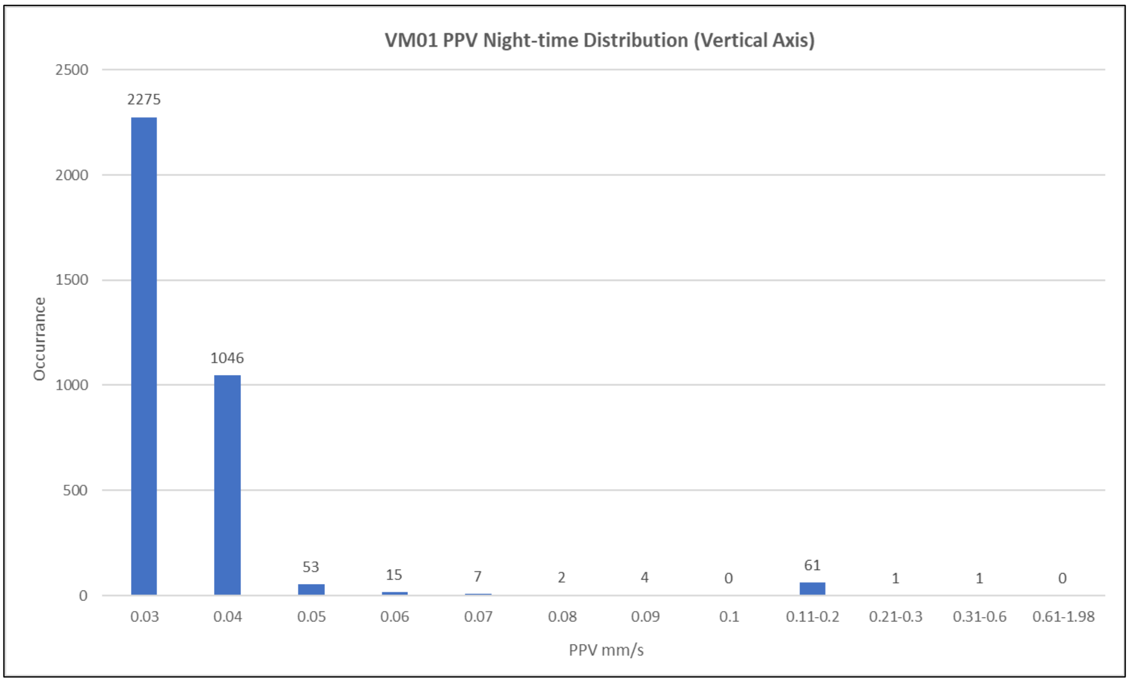

Figure 8 Night-time PPV Z – axis Distribution – VM01

PPV values are in the range of 0.03 to 0.09mm/s in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.11 to 0.02mm/s. The dominant frequency associated with a train pass by is in the range of 20 to 40Hz. A minor number of PPV events were recorded in the range of 0.2 to 0.6mm/s over night-time periods which are also potentially attributed to rail pass by's, although the higher values may also be attributed to activities within the garden.

3.1.2 Vibration Dose Value

Measured VDV values for each axis are summarised in Table 4. The data is presented in terms of the $VDV_{,b/dday}$ and $VDV_{,\,b/d,night}$ for each axis, the baseline VDV value in the absence of any passing trains and the VDV value associated with a train pass by's.

Axis	Daytime (07:00-23:00Hrs)		Night-time (23:00 – 07:00hrs)		Typical train pass by VDV ($m/s^{1.75}$)
	$VDV_{,day}$ ($m/s^{1.75}$)	Baseline, VDV ($m/s^{1.75}$)	$VDV_{,\,night}$ ($m/s^{1.75}$)	Baseline VDV ($m/s^{1.75}$)	
X (Wd)	0.01 – 0.02	0.0003	0.002 - 0.003	0.0003	0.001 – 0.002
Y (Wd)	0.01	0.0003	0.002 - 0.004	0.0003	0.001 – 0.002
Z (Wb)	0.03 – 0.05	0.0003	0.011 – 0.015	0.0003	0.002 – 0.01

Table 4 VDV values for VM01

The baseline VDV at this monitoring location is low with both day and night-time VDV values significantly below levels associated with adverse response in accordance with BS 6472 (2008) Part 2.

Figures 9 and 10 presents the plotted time history graph for the vertical axis for individual VDV events measured over day and night-time periods respectively over the 6 day monitoring period.

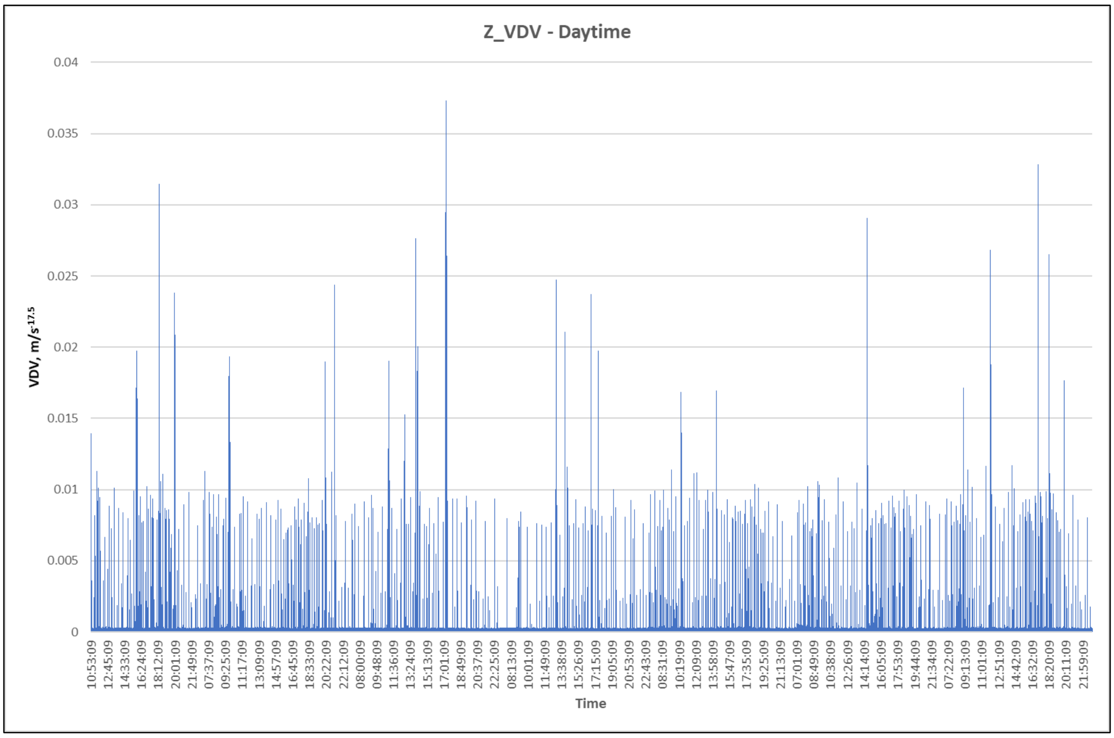

Figure 9 VM01: Daytime VDV events z–axis

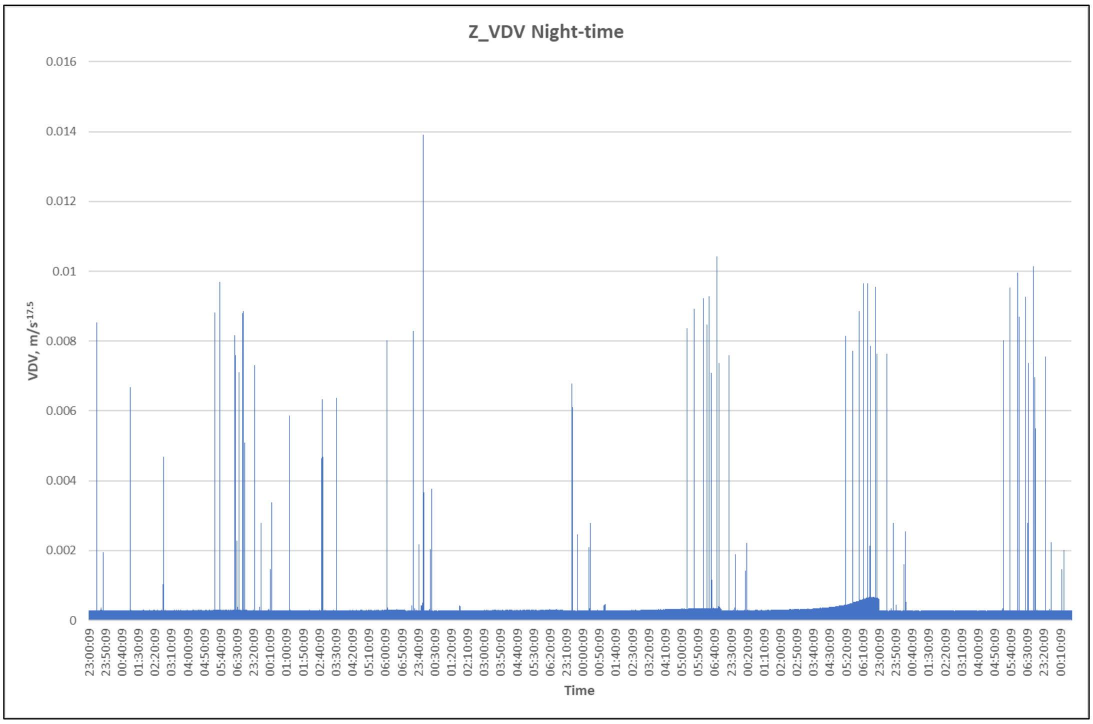

Figure 10 VM01: Night-time VDV z–axis

3.2 VM02 – O'Connell Street

At VM02, the accelerometer was positioned to the rear of a scaffold façade along O'Connell street, at a vacant site adjacent to Dr. Quirkeys. The monitoring position was approximately 25m from the nearside Luas Cross City rail line.

The monitoring data has been reviewed against the Luas rail time tables to align measurement periods against passing train times along the adjacent rail line. Measured vibration values significantly in excess of those associated with train pass by's have been removed as outlier values associated with the activities at the accelerometer which were noted to occur for a small number of periods.

3.2.1 <u>Peak Particle Velocity</u>

Table 5 summarises the monitoring results for this location for the horizontal and vertical axes. The range of maximum, minimum and median PPV values recorded over each daytime period (07:00 to 23:00hrs) and each night-time period (23:00 to 07:00hrs) over the 8 day monitoring period are presented. The typical PPV value associated with train pass by's are also included.

Axis	Daytime (07:00-23:00Hhrs)			Night-time (23:00 – 07:00hrs)			Typical train pass by - PPV (mm/s)
	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	
X	0.05 – 0.14	0.03	0.04	0.05 – 0.06	0.03	0.03	0.04 – 0.06
Y	0.07 – 0.2	0.03	0.04	0.05 – 0.13	0.03	0.03	0.05 – 0.1
Z	0.15 – 0.4	0.03	0.04	0.07 – 0.13	0.03	0.03	0.05 – 0.08

Table 5 PPV values for VM02

Figure 11 presents the distribution of measured PPV values over the 8 day monitoring period during daytime hours (07:00 to 23:00hrs) for the vertical axis.

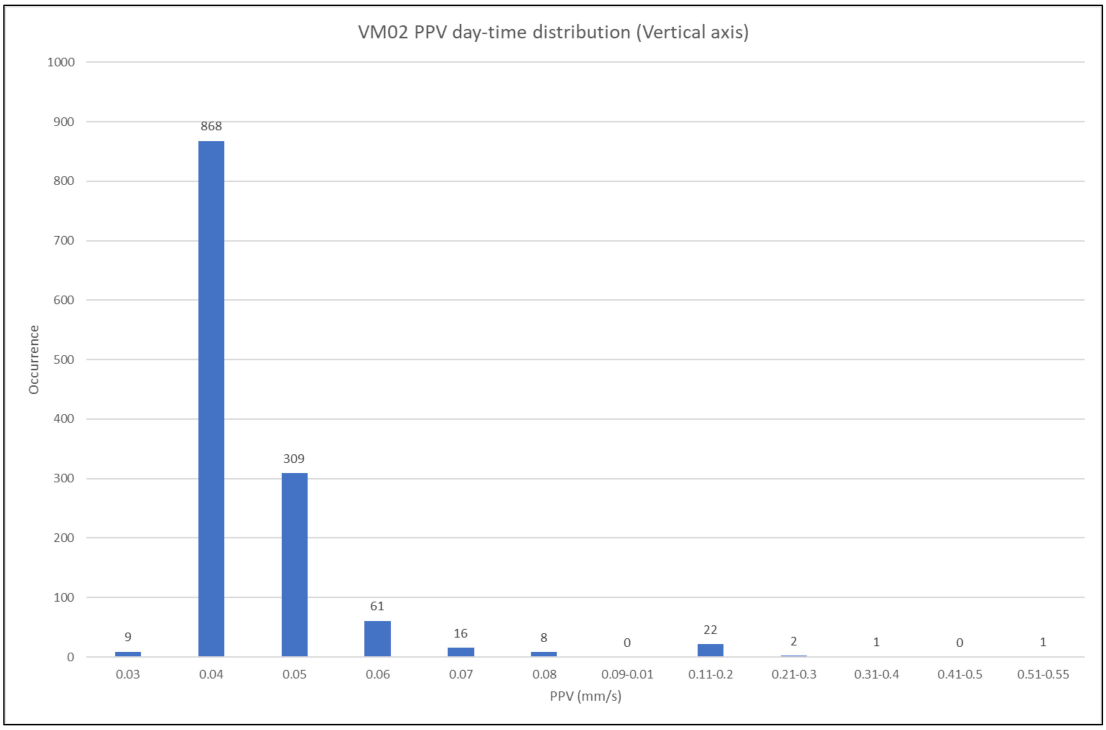

Figure 11 VM02: Daytime PPV Vertical Distribution

PPV values are in the range of 0.03 to 0.04 in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.05 to 0.08mm/s. The dominant frequency associated with a train pass by is in the range of 15 to 20Hz. A low number of PPV events were recorded in the range of 0.1 to 0.5mm/s over day and night-time periods which are also potentially attributed to rail pass by's. The maximum events recorded are expected, however, to be as a result of activities adjacent to the accelerometer.

Figure 12 presents the distribution of measured PPV values over the 8 day monitoring periods during night-time hours (23:00 to 07:00hrs) for the vertical axis.

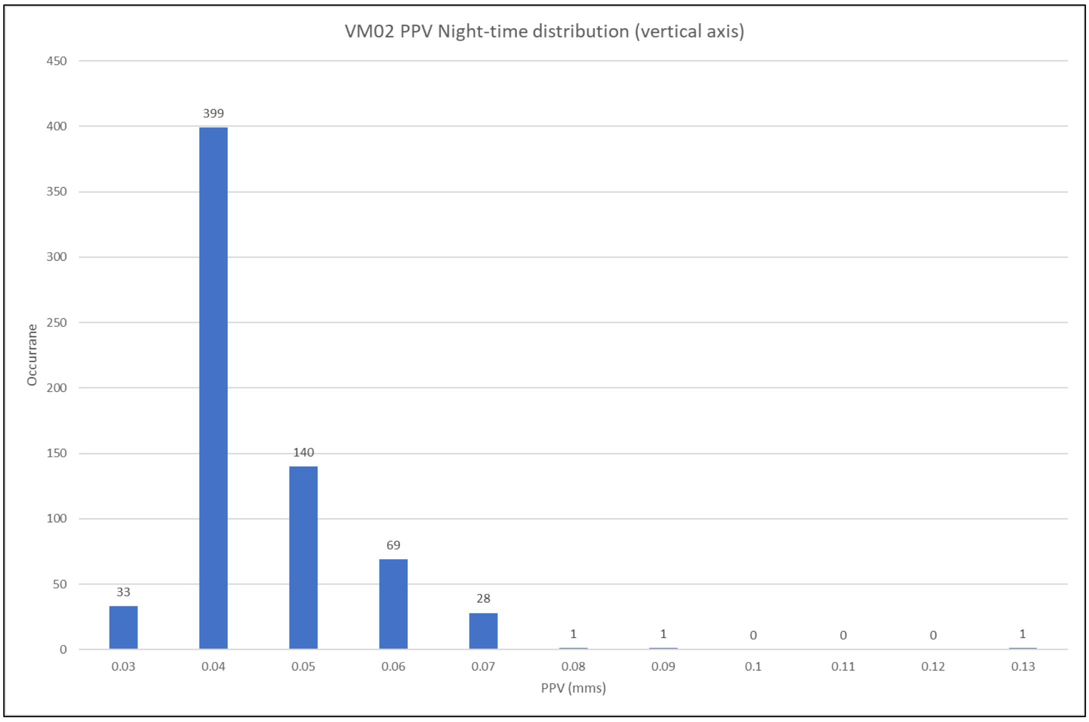

Figure 12 VM02: Night-time PPV Vertical Distribution

PPV values are in the range of 0.03 to 0.04mm/s in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.05 to 0.07mm/s. The dominant frequency associated with a train pass by is in the range of 20 to 40Hz.

3.2.2 Vibration Dose Value

Measured VDV values for each axis are summarised in Table 6. The data is presented in terms of the $VDV_{,b/dday}$ and $VDV_{,\,b/d,night}$ for each axis, the baseline VDV value in the absence of any passing trains and the VDV value associated with a train pass by's.

Axis	Daytime (07:00-23:00Hrs)		Night-time (23:00 – 07:00hrs)		Typical train pass by VDV ($m/s^{1.75}$)
	$VDV_{,day}$ ($m/s^{1.75}$)	Baseline, VDV ($m/s^{1.75}$)	$VDV_{,\,night}$ ($m/s^{1.75}$)	Baseline VDV ($m/s^{1.75}$)	
X (Wd)	0.001 – 0.002	0.0003	0.001	0.0003	n/a
Y (Wd)	0.001 – 0.002	0.0003	0.001	0.0003	n/a
Z (Wb)	0.006 – 0.03	0.0003	0.004 – 0.005	0.0003	0.001 – 0.0015

Table 6 VDV values for VM02

n/a: For the horizontal axes, passing rail events were not discernible above the baseline measured data.

The baseline VDV at this monitoring location is low with both day and night-time VDV values significantly below levels associated with adverse response in accordance with BS 6472 (2008) Part 2.

Figures 13 and 14 presents the plotted time history graph for the vertical axis for individual VDV events measured over day and night-time periods respectively over the 8 day monitoring period. In Figure 13, the higher results at the end of the survey period relate to movement adjacent to the accelerometer during collection.

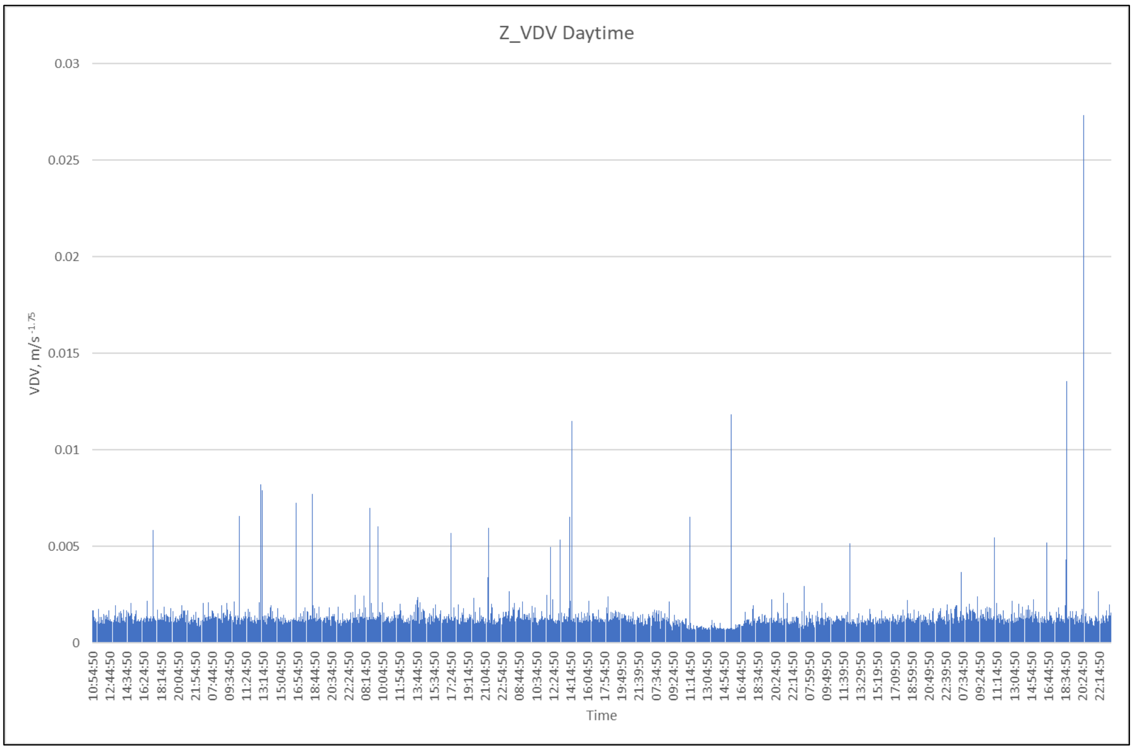

Figure 13 VM02: Daytime VDV event z–axis

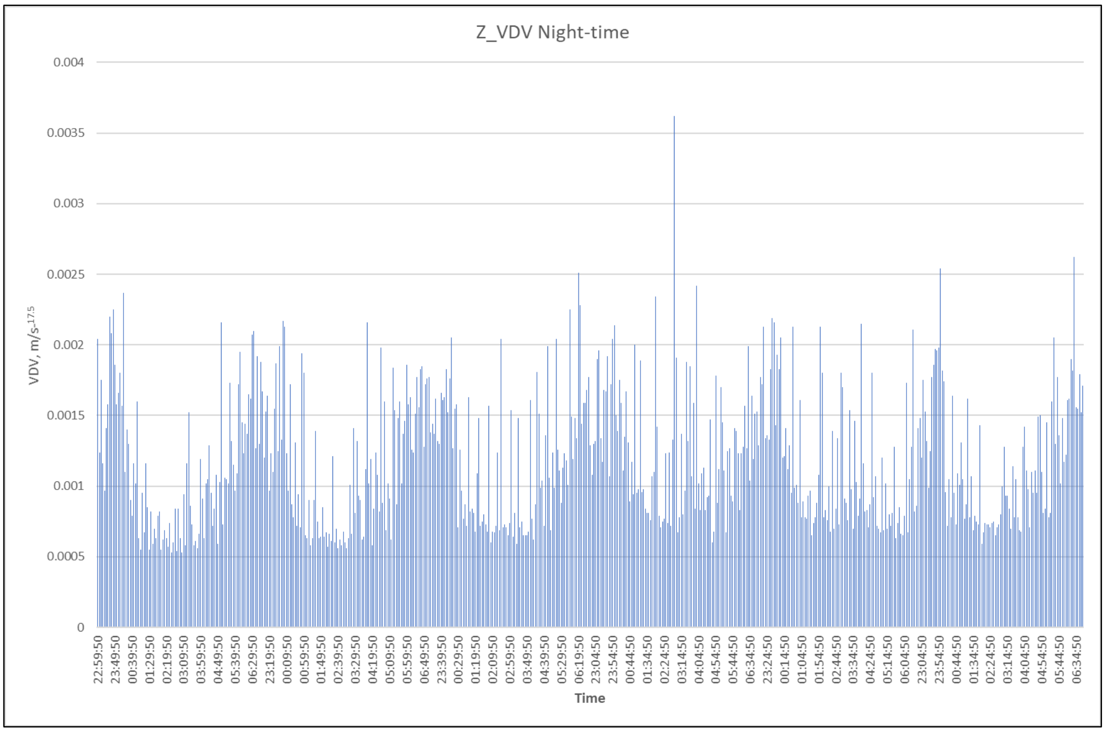

Figure 14 VM02: Night-time VDV event z–axis

3.3 VM03 – Charlemont

At VM03, the accelerometer was positioned at ground level at approximately 2m from the base of the Luas rail embankment. The rail line is at a height of approximately 4m above ground level.

The monitoring data has been reviewed against the Luas rail time tables to align measurement periods against passing train times along the adjacent rail line. Measured vibration values significantly in excess of those associated with train pass by's have been removed as outlier values associated with the activities at the accelerometer which were noted to occur for a small number of periods.

3.3.1 Peak Particle Velocity

Table 7 summarises the monitoring results for this location within the three measured axis. The results are presented in terms of the range of maximum PPV values recorded over each daytime period (07:00 to 23:00hrs) and each night-time period (23:00 to 07:00hrs) over the 5 day monitoring period.

Review of the data set identified a small number of outlier values above 0.3mm/s on individual occasions during day and night-time periods. These peak values are associated with a specific event likely to be as a result of local activity adjacent to the accelerometer. These measurement results have been removed from the data sets in the summary table below.

Axis	Daytime (07:00-23:00Hrs)			Night-time (23:00 – 07:00hrs)			Typical train pass by - PPV (mm/s)
	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	Maximum PPV mm/s	Minimum PPV mm/s	Median PPV (mm/s)	
X	0.1 – 0.2	0.02	0.03	0.1 – 0.2	0.02	0.03	0.05 – 0.08
Y	0.1 – 0.25	0.02	0.03	0.1 – 0.25	0.02	0.03	0.05 – 0.08
Z	0.1 – 0.2	0.02	0.04	0.1 – 0.2	0.03	0.04	0.05 – 0.12

Table 7 PPV values for VM02

Figure 15 presents the distribution of measured PPV values over the 5 day monitoring periods during daytime hours (07:00 to 23:00hrs) for the vertical axis. The dataset includes all data, including the outlier values above 0.3mm/s.

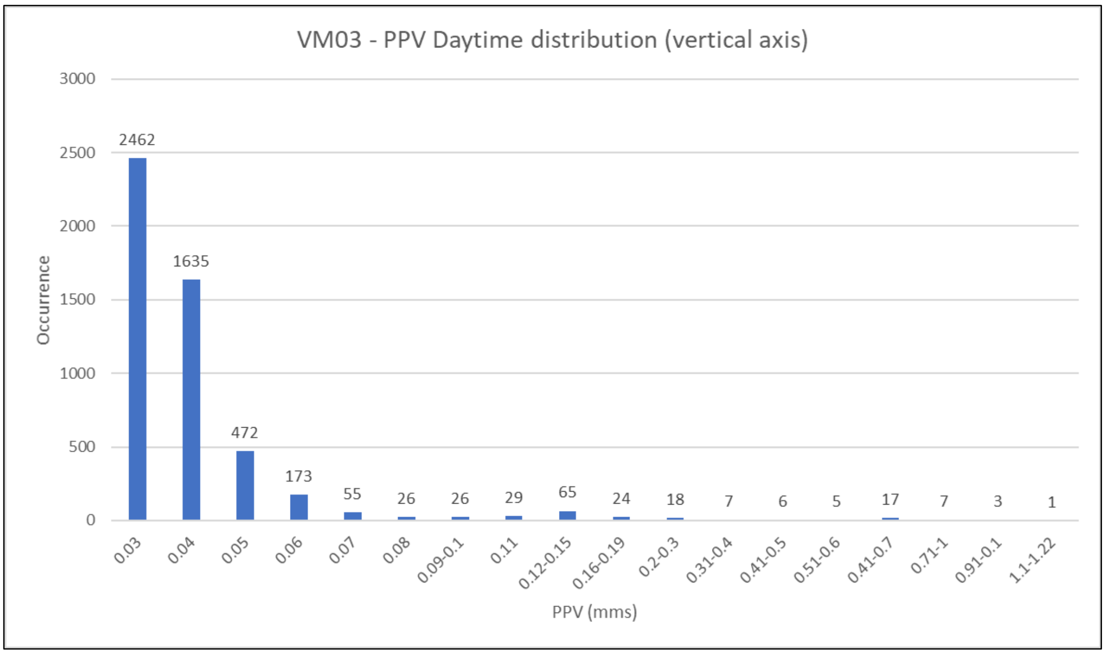

Figure 15 VM03: Daytime PPV Vertical Distribution

Baseline measured PPV values are in the range of 0.03 to 0.04mm/s in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.05 to 0.12mm/s. The dominant frequency associated with a train pass by is in the range of 0.5 to 2Hz. Measured PPV values above these events are noted to be outliers in the data set.

Figure 16 presents the distribution of measured PPV values over the 6 day monitoring periods during night-time hours (23:00 to 07:00hrs) for the vertical axis. The data set includes all data, including the outlier values above 0.3mm/s.

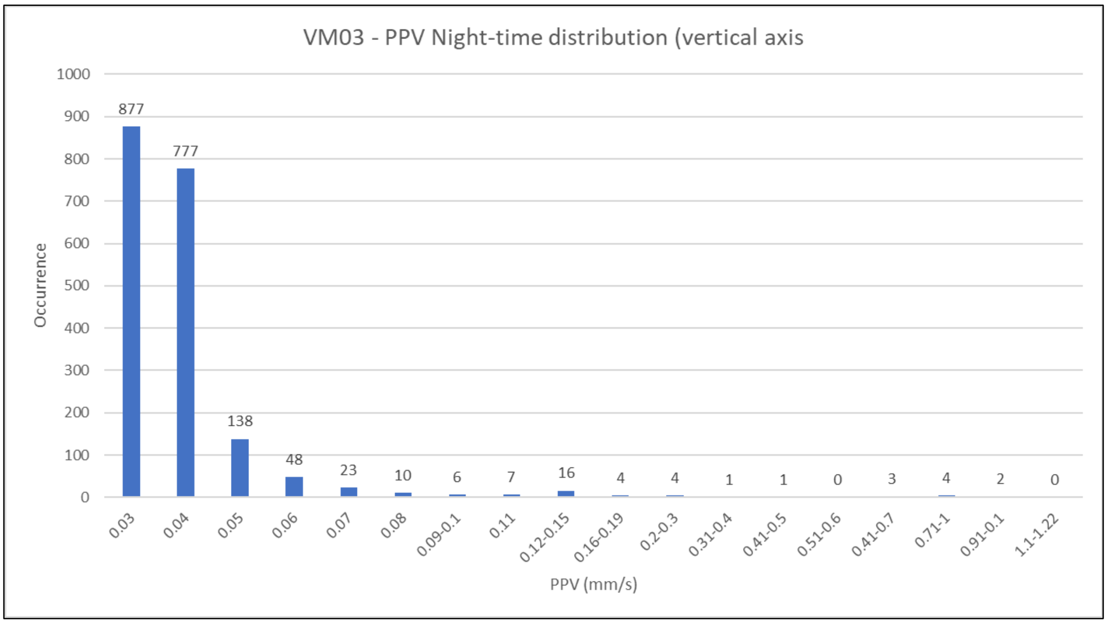

Figure 16 Daytime PPV Z – axis Distribution – VM03

Baseline measured PPV values are in the range of 0.03 to 0.04 in the absence of passing trains. During a passing train event, measured PPV values are measured in the range of 0.05 to 0.12mm/s. The dominant frequency associated with a train pass by is in the range of 0.5 to 2Hz. Measured PPV values above these events are noted to be outliers in the data set.

3.3.2 Vibration Dose Value

Measured VDV values for each axis are summarised in Table 8. The data is presented in terms of the $VDV_{,b/dday}$ and $VDV_{,\ b/d,night}$ for each axis, the baseline VDV value in the absence of any passing trains and the VDV value associated with a train pass by's.

Similar to the PPV data set above, noted outlier data points have been removed from the summary baseline table. For the VDV data set, this relates to measured values above 0.008 $m/s^{1.75}$.

Axis	Daytime (07:00-23:00Hrs)		Night-time (23:00 – 07:00hrs)		Typical train pass by VDV ($m/s^{1.75}$)
	$VDV_{,day}$ ($m/s^{1.75}$)	Baseline, VDV ($m/s^{1.75}$)	$VDV_{,\ night}$ ($m/s^{1.75}$)	Baseline VDV ($m/s^{1.75}$)	
X (Wd)	0.001 - 0.003	0.0003	0.001 - 0.003	0.0003	0.0003 – 0.00035
Y (Wd)	0.001 - 0.003	0.0003	0.001 - 0.003	0.0003	0.0003 – 0.0004
Z (Wb)	0.008 – 0.014	0.0004	0.005 – 0.012	0.0004	0.001 – 0.002

Table 8 VDV values for VM03

The baseline VDV at this monitoring location is low with both day and night-time VDV values significantly below levels associated with adverse response in accordance with BS 6472 (2008) Part 2.

Figures 17 and 18 presents the plotted time history graph for the vertical axis for individual VDV events measured over day and night-time periods over the 6 day monitoring period for all measured data including outlier data.

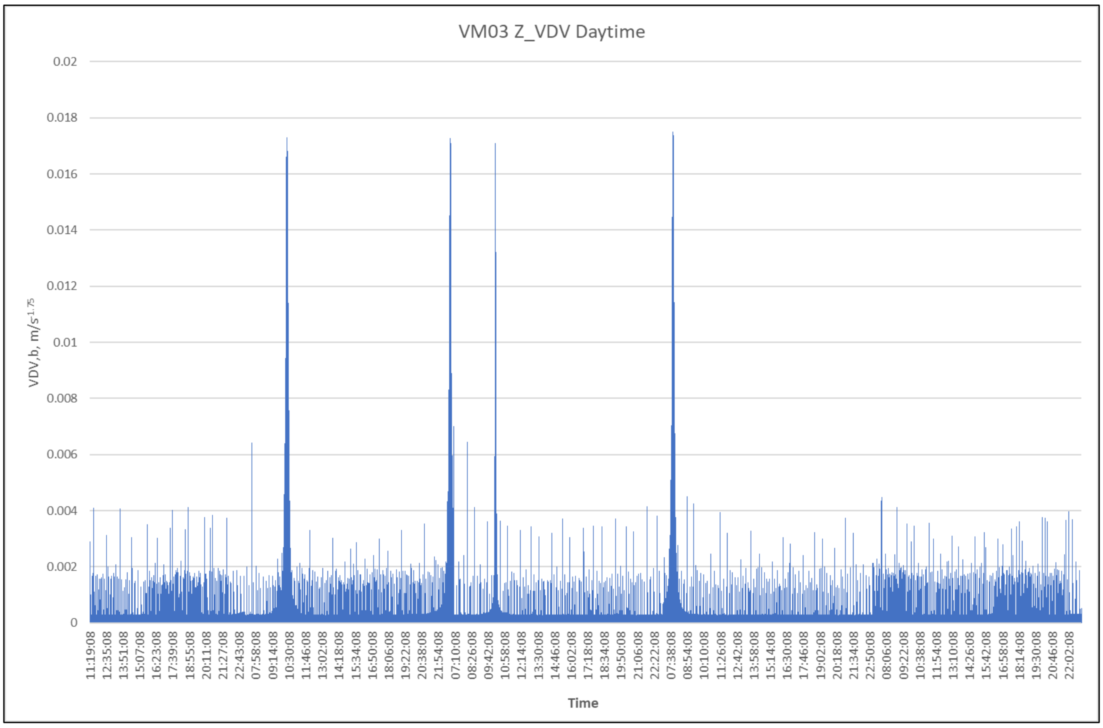

Figure 17 Daytime VDV z–axis: VM03

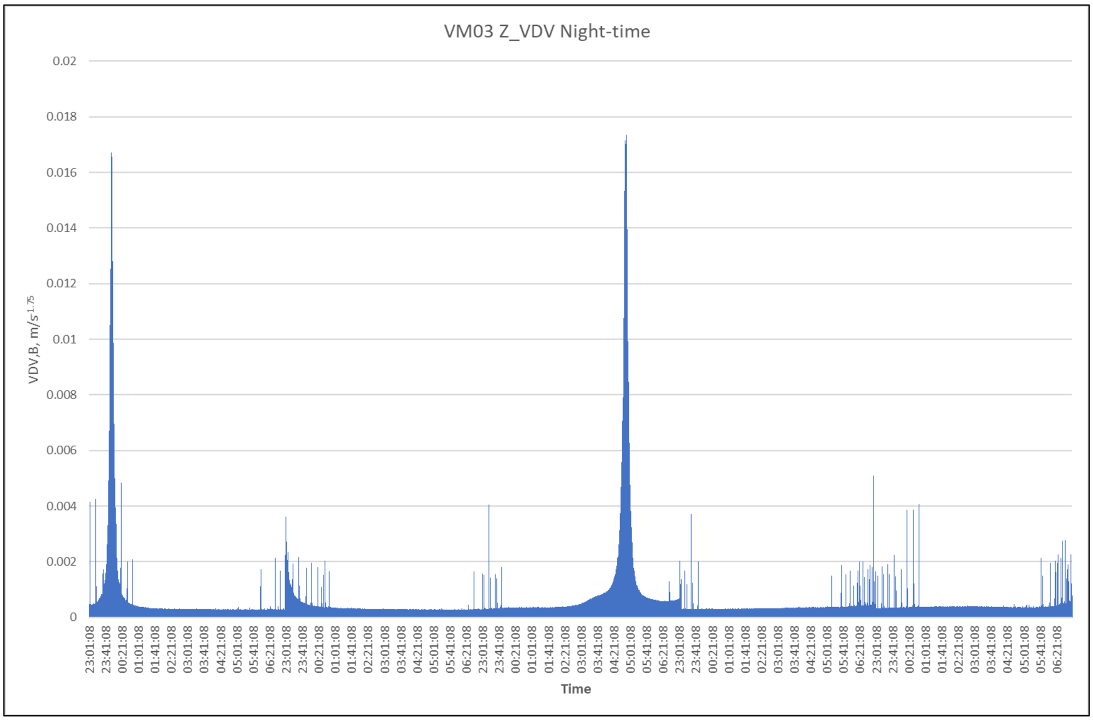

Figure 18 Night-time VDV z–axis: VM03

4.0 SUMMARY AND CONCLUSIONS

Baseline vibration monitoring has been undertaken at three monitoring locations as part of the baseline study for the airborne noise and vibration chapter of the Metrolink EIAR.

Vibration monitoring has been undertaken at three locations across the study area chosen to represent sensitive buildings and or locations adjacent to existing rail lines.

The baseline vibration environment at all three locations is low. Vibration levels associated with passing rail was detectable above the baseline environment at all three locations. The overall range of vibration levels measured at all locations, was however, low and would not give rise to levels of vibration typically perceptible to building occupants.

The existing baseline VDV_{day} and $VDV_{,night}$ values are below a value where a *low probability of adverse comment* would be expected within a building as defined within BS 6472-1 (2008) at all three locations.

APPENDIX A

Calibration Certificate for Monitoring Equipment
RION VM-56 - Serial Number 680043

CERTIFICATE OF CALIBRATION

Date of Issue: 01 November 2019

Certificate Number: TCRT19/1825

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk
Acoustics Noise and Vibration Ltd trading as ANV Measurement Systems

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Approved Signatory

K. Mistry

Client	AWN Consulting Limited The Tecpro Building, IDA Business & Technology Park, Clonshaugh Dublin 17 Ireland
Purchase Order No.	DOD/19/Cal03
Instrument	Rion VM-56 Tri-Axial Vibration Meter
Serial No.	00680043
Accelerometer Type	VM-56
Accelerometer Serial No.	80047
Program	2.0
Client Asset No.	N/A
Procedure ID.	VM-56 Issue 1
Job Number	TRAC19/11477
Date of Calibration	01 Nov 2019
Previous Cert. number	N/A
Date of Previous Cert.	N/A
Rig Number	6
Kit Number	24
Calibration Status	**Passed Calibration**

This calibration is traceable to National Standards. ANV Measurement Systems sources used to perform calibrations are calibrated at the National Physical Laboratory or by UKAS laboratories accredited for the purpose.

The performance of the system (the meter, accelerometer) was found to be within the manufacturer's specification.

Comment
This certificate reports recorded values for the instrument 'As Received'.

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Environment
The ambient environmental conditions at the time of the calibration were;
Temperature: 22.9 ± 1°C, Humidity: 40 ± 5%RH, Atmospheric pressure 98.2 ± 1 kPa

Test results
Each accelerometer axis was mounted co-axially with a Rion LS-10C servo accelerometer, and tests conducted for the dynamic range, PPV linearity and frequency response of the complete system. Additional electrical tests were carried out on the amplitude linearity of the instrument.

PPV linearity response for the complete system at 16 Hz With PV-83CW serial No. 80047
Weightings for all channels turned OFF

Target Vel. mm/s	Actual Vel. mm/s	Indicated (X) mm/s	Error (X) %	Indicated (Y) mm/s	Error (Y) %	Indicated (Z) mm/s	Error (Z) %
0.50	0.51	0.57	11.56	0.55	7.65	0.54	5.69
1.00	1.02	1.09	6.67	1.08	5.69	1.06	3.73
2.50	2.55	2.67	4.51	2.66	4.12	2.60	1.77
5.00	5.11	5.31	3.93	5.30	3.73	5.18	1.38
10.00	10.13	10.59	4.50	10.43	2.92	10.35	2.13
20.00	20.27	21.24	4.80	21.03	3.76	20.61	1.69

Permitted tolerance ± 10% ± 1 LSD (Least Significant Digit).

Linearity errors in dB measured electrically at 40 Hz
Weightings for all channels turned OFF
Level changes in dB; reading error in dB given for each axis. "m/s^2" is actual reading in m/s^2.

1 m/s^2 Range

Level dB	Error (X) dB	m/s^2 (X)	Error (Y) dB	m/s^2 (Y)	Error (Z) dB	m/s^2 (Z)
0	REF	0.98154	REF	0.98129	REF	0.98130
-20	-0.01	0.09805	-0.01	0.09802	-0.01	0.09803
-40	-0.02	0.00979	-0.02	0.00979	-0.02	0.00979
-60	-0.10	0.00097	-0.10	0.00097	-0.10	0.00097
-66	-0.03	0.00049	-0.21	0.00048	-0.03	0.00049
-72	-0.23	0.00024	-0.23	0.00024	-0.23	0.00024

Permitted tolerance ±1.0 dB.

10 m/s^2 Range

Level dB	Error (X) dB	m/s^2 (X)	Error (Y) dB	m/s^2 (Y)	Error (Z) dB	m/s^2 (Z)
20	-0.03	9.79122	-0.03	9.75526	-0.03	9.73534
0	REF	0.98208	REF	0.97857	REF	0.97679
-20	-0.01	0.09808	-0.01	0.09775	-0.01	0.09758
-30	-0.01	0.03102	-0.03	0.03085	-0.06	0.03067
-40	0.04	0.00987	-0.02	0.00976	0.02	0.00979
-52	-0.31	0.00238	0.69	0.00266	-0.01	0.00245

Permitted tolerance ±1.0 dB.

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Frequency Responses For Complete System

Measured on the 1 m/s^2 range with weightings as indicated in the table and PV-83CW serial No. 80047

Frequency Hz	Applied Acc. m/s^2	X (Wd) rms m/s^2	Error X %	VDV (X) $m/s^{1.75}$	Error X %
3.981	0.285	0.15654	5.4	0.30765	5.3
5.012	0.355	0.15445	5.2	0.30359	5.1
6.310	0.355	0.12187	5.1	0.23974	5.0
7.943	0.355	0.09586	4.5	0.18849	4.4
10.00	0.355	0.07622	4.9	0.14987	4.8
12.59	0.355	0.06052	5.3	0.11912	5.3
15.85	0.355	0.04836	6.2	0.09515	6.2
19.95	0.550	0.06014	7.3	0.11834	7.3

Frequency Hz	Applied Acc. m/s^2	Y (Wd) rms m/s^2	Error Y %	VDV (Y) $m/s^{1.75}$	Error Y %
3.981	0.285	0.15640	5.3	0.30743	5.2
5.012	0.355	0.15372	4.7	0.30199	4.5
6.310	0.355	0.12149	4.7	0.23878	4.6
7.943	0.355	0.09627	5.0	0.18928	4.9
10.00	0.355	0.07622	4.9	0.14987	4.8
12.59	0.355	0.06054	5.3	0.11907	5.3
15.85	0.355	0.04850	6.5	0.09539	6.5
19.95	0.550	0.06064	8.2	0.11932	8.2

Frequency Hz	Applied Acc. m/s^2	Z (Wb) rms m/s^2	Error Z %	VDV (Z) $m/s^{1.75}$	Error Z %
3.981	0.285	0.26307	3.0	0.52192	3.8
5.012	0.355	0.37779	2.4	0.74853	3.1
6.310	0.355	0.38731	2.1	0.76723	2.7
7.943	0.355	0.37632	2.0	0.74338	2.4
10.00	0.355	0.35641	1.6	0.70262	1.7
12.59	0.355	0.32928	1.2	0.64883	1.3
15.85	0.355	0.29668	1.3	0.58400	1.3
19.95	0.550	0.39872	0.8	0.78497	0.8
25.12	0.550	0.33640	3.3	0.66184	3.3
31.62	0.550	0.27597	2.9	0.54310	2.9
39.81	0.550	0.21843	1.0	0.42982	1.0
50.12	0.550	0.17703	3.4	0.34836	3.3
63.10	0.550	0.13695	3.8	0.26950	3.8
79.43	0.550	0.10077	4.1	0.19832	4.1

Tolerance required @ 4 Hz to 63 Hz +12%/-11% ; @ 80 Hz +26%/-21%

All results meet the manufacturer's specification.

END OF CALIBRATION **CALIBRATED BY :- A. Lloyd**