Using OBSI measurements of road surface corrections to improve noise modelling predictions

Antony Williams[1], Dominic Sburlati[2] and Matthew Harrison[3]

[1]SLR Consulting Australia Pty Ltd, NSW Australia
[2]SLR Consulting Australia Pty Ltd, NSW Australia
[3]Pulse Acoustic Consultancy Pty Ltd, NSW Australia

ABSTRACT

The prediction of road traffic noise using noise models is a common feature of Environmental Assessments and Development Applications. The outputs of noise models are used to determine the requirements for noise mitigation for a project, which can easily amount to several million dollars in value on large projects. It is therefore important to have reliable modelling results which adequately represent a project's impacts and that correlate well with noise levels measured in the real world. Road surface corrections have been measured using SLR's innovative 3D printed On-Board Sound Intensity (OBSI) system for the eastbound and westbound carriageway of a test section of the M4 Motorway. The OBSI road surface corrections have been applied to a noise model and compared to the use of 'standard' road surface corrections. The noise predictions in both scenarios have been referenced to noise monitoring data at nine locations within the study area. The results of the modelling show that the predictions which make use of the OBSI road surface corrections correlate better with the measured noise level data when compared to the scenario using 'standard' corrections. The OBSI corrections were found to improve both the median error and the standard deviation of the dataset.

1. INTRODUCTION

The On-Board Sound Intensity (OBSI) method measures tyre-pavement noise at the source using microphones in a sound intensity probe configuration mounted to a test vehicle. Real time noise measurements are performed whilst the test vehicle drives along a pavement of interest.

OBSI measurements use a dual probe fixture configuration and a reference test tyre. The National Cooperative Highway Research Program (NCHRP) project 1-44 documents the more critical aspects of the OBSI test protocol (CHRP, 2009). The OBSI method was first standardised by the American Association of State Highway and Transportation Officials (AASHTO) in 2008 and has undergone annual updates as provisional standard TP 76, "Standard Method of Test for Measurement of Tyre/Pavement Noise Using the On-Board Sound Intensity (OBSI) Method" (AASHTO, 2013).

The measurement setup used by OBSI requires that the probes be located close to the leading and trailing edge of the contact patch of the tyre-pavement interface. Research has shown that the tyre-pavement noise, measured by passby measurements, can be well described by direct measurements made at these two locations (Rasmussen, 2011). The OBSI test measurement setup is shown in Figure 1.

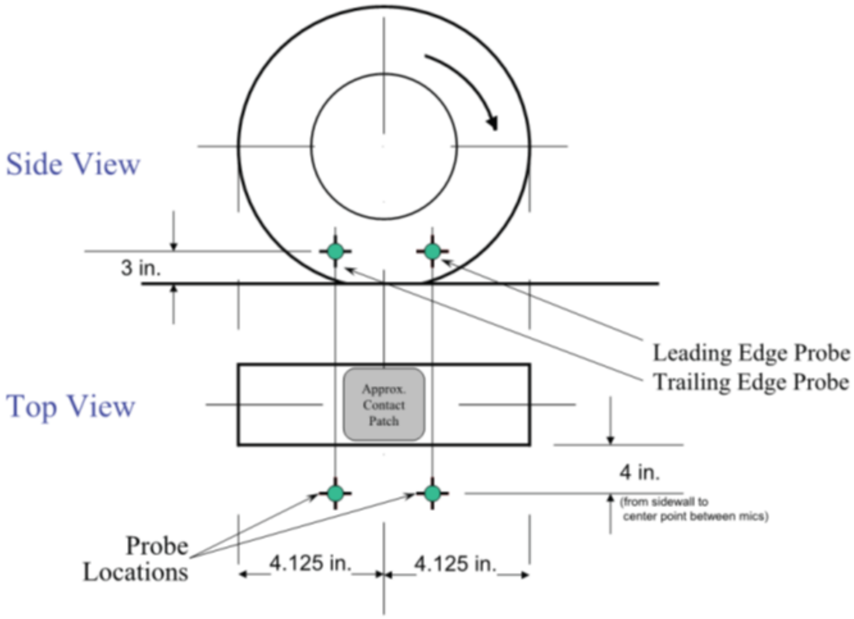

Figure 1: Sound intensity probe positions with respect to the tyre-pavement interface

SLR has recently designed and developed a low cost 3D printed prototype OBSI system (Cockings, et al. 2015). Examples of the prototype CAD models are shown in Figure 2.

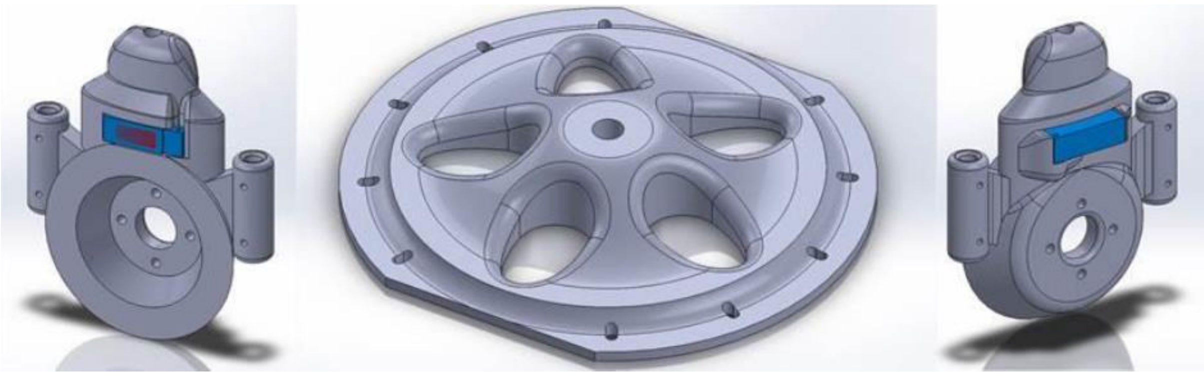

Figure 2: 3D models of SLR OBSI test components

2. THE PREDICTION OF ROAD TRAFFIC NOISE AND OBSI

The prediction of road traffic noise using computer noise models is a common feature of Environmental Assessments and Development Applications. Providing the affected community and stakeholders with detailed and transparent noise predictions assists in providing assurance that a rigorous and scientific approach to potential noise impacts and mitigation options has been implemented.

The outputs of noise models are used to determine the requirements for noise mitigation for a project (typically including areas of low noise pavement, noise barriers and at-property treatment), which can easily amount to several million dollars in value on large projects. It is therefore important to have reliable modelling results which adequately represent a project’s impacts and that correlate well with noise levels measured in the real world.

A key feature of developing a robust noise model is determining the road surface type and its corresponding noise emission characteristics. Different road surfaces have different noise emissions, which can vary significantly even for the same surface type. In practice, the road surface type may change along a section of road and may even differ between lanes, resulting in a highly variable noise emission level.

It is not yet common practice for acoustic consultants to determine road surface corrections by measurement, which can make it difficult to implement representative road surface corrections for projects with long alignments or on carriageways with different surface types. A key feature of OBSI derived surface corrections is that a surface correction value (in dB) is measured in one second intervals, which provides a high spatial resolution output. Road surface correction profiles are able to be measured for each carriageway independently. Profiles for individual lanes are also able to be measured if required.

The usual method of modelling road noise is to apply 'standard' road surface corrections that are based solely on the pavement surface type in question. Example standard pavement corrections are provided in Table 1, with the corrections being relative to Dense Graded Asphalt, which has a correction of 0 dB.

Table 1: Example 'standard' road surface correction

Pavement surface type	Road surface correction (dB)
Dense graded asphalt (DGA)	0
Open graded asphalt (OGA)	-2 or -2.5
Stone mastic Asphalt (SMA)	-2
Concrete	+3

Noise models are typically calibrated/validated using noise monitoring data and concurrently measured traffic data within a project area. As a relatively small sample size of noise monitoring locations are typically used to validate most noise models, there is potential for increased levels of error to be introduced into the process.

The noise performance of most road surfaces is known to degrade over time, which can be especially true for low noise road surfaces such as OGA. When assuming 'standard' corrections for these types of surfaces in the modelling process, there is potential for significant levels of error to be apparent where a surface has deviated from the 'standard' correction due to age and wear rate. A key aim of using OBSI derived surface corrections is therefore to aid in reducing the systematic error which is potentially inherent in noise modelling.

3. A NOISE MODELLING CASE STUDY USING OBSI

3.1 Methodology

Noise monitoring adjacent to the M4 Motorway was undertaken at a number of locations by SLR on a recent road infrastructure project. This motorway was selected as it is known to have an OGA pavement surface that varies notably in both age and condition.

OBSI measurements of the M4 Motorway were undertaken by SLR to determine high resolution road surface corrections for the full length of the assessment area. Multiple OBSI measurements were completed in both the eastbound and westbound direction to allow an average for each carriageway to be determined. All measurements were performed with a vehicle speed of approximately 80 km/h. Measurements that significantly deviated from the target speed were discounted.

Noise levels were predicted to the noise monitoring locations using a SoundPLAN noise model which implemented the Calculation of Road Traffic Noise (CoRTN, 1988) algorithms. Two scenarios were modelled – one making use of 'standard' road surface corrections (as per Table 1) and one using the high resolution OBSI measured surface corrections. Noise predictions were undertaken using measured traffic data for the 11 am to 3 pm period and compared to the measured noise level data during the same period. This period was used as it is known to be free flowing and therefore less affected by traffic congestion.

Nine noise monitoring locations were selected from the dataset. Locations were used that typically had unobstructed views of the main motorway carriageway and were not unduly affected by features such as being close to adjacent roads, near to garden fences, etc. Setback distances of the monitoring locations were typically around 20 m to 50 m from the carriageway.

3.2 Model Inputs – OBSI Road Surface Corrections

The measured intensity data from the OBSI test runs was processed to give road surface corrections in one second intervals for both carriageways. The measured OBSI road surface corrections are shown below in Figure 3 and Figure 4 for the eastbound and westbound carriageway, respectively. The graphs represent a test section of the M4 Motorway that is approximately 28 km in length. It is understood that the surface type for the majority of the test section is OGA, although the age and condition of the surface varies significantly.

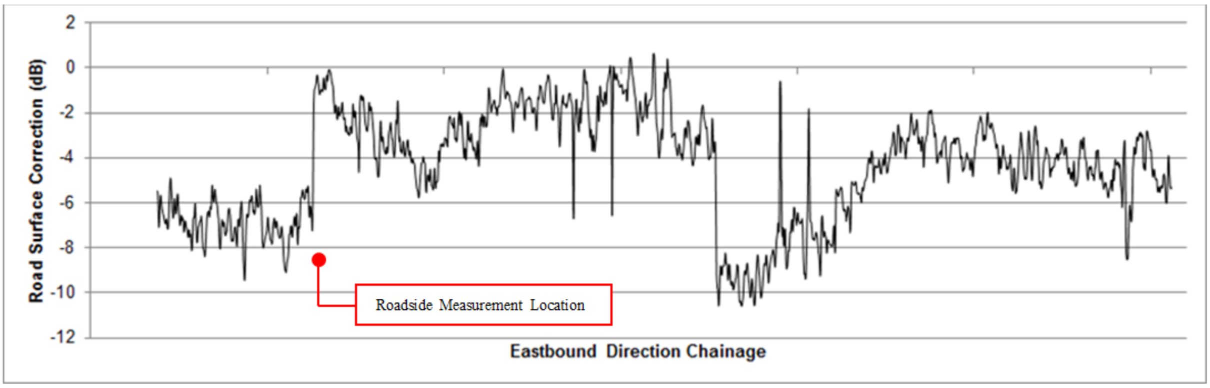

Figure 3: Measured OBSI road surface correction – eastbound direction

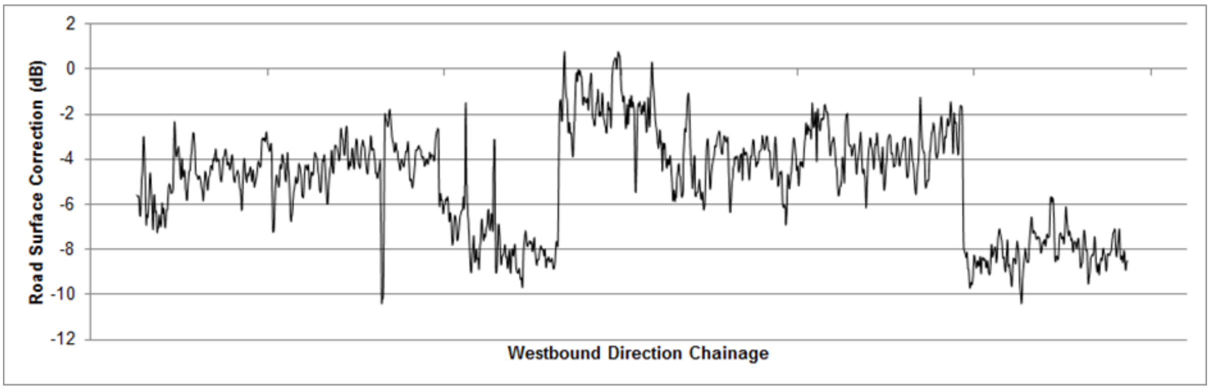

Figure 4: Measured OBSI road surface correction – westbound direction

The OBSI road surface corrections can be seen to vary between approximately 0 dB and -9 dB in both carriageway directions. This is notably different from the standard -2 dB that is typically assumed in modelling of road traffic noise for this surface type (as per Table 1).

The figures shown that there are two locations on both carriageways where large step changes, in the order of 6 dB, are apparent. These are locations where the surface type abruptly changes from worn OGA to relatively newly resurfaced pavement.

3.2.1 OBSI road surface corrections vs roadside measurements

To further validate the road surface corrections derived from the SLR OBSI system, a series of roadside noise measurements were made on a selected section of the M4 Motorway. Measurements were made adjacent to a flat section of the eastbound carriageway where a large step change in OBSI road surface correction was measured (noted in Figure 3). In this location the road surface changes from relatively new OGA to worn OGA.

Measurements were made using six noise loggers positioned at a distance of 4 m from the edge of the nearside carriageway to measure vehicle passby noise. One noise logger was positioned adjacent to the location of the change in surface type (shown by the red circle in Figure 5), with the other noise loggers being spaced at intervals of 10 m in either direction.

The noise loggers were deployed for several hours during an early afternoon period whilst the motorway was free flowing. Vehicles were noted as having a constant speed through the test section.

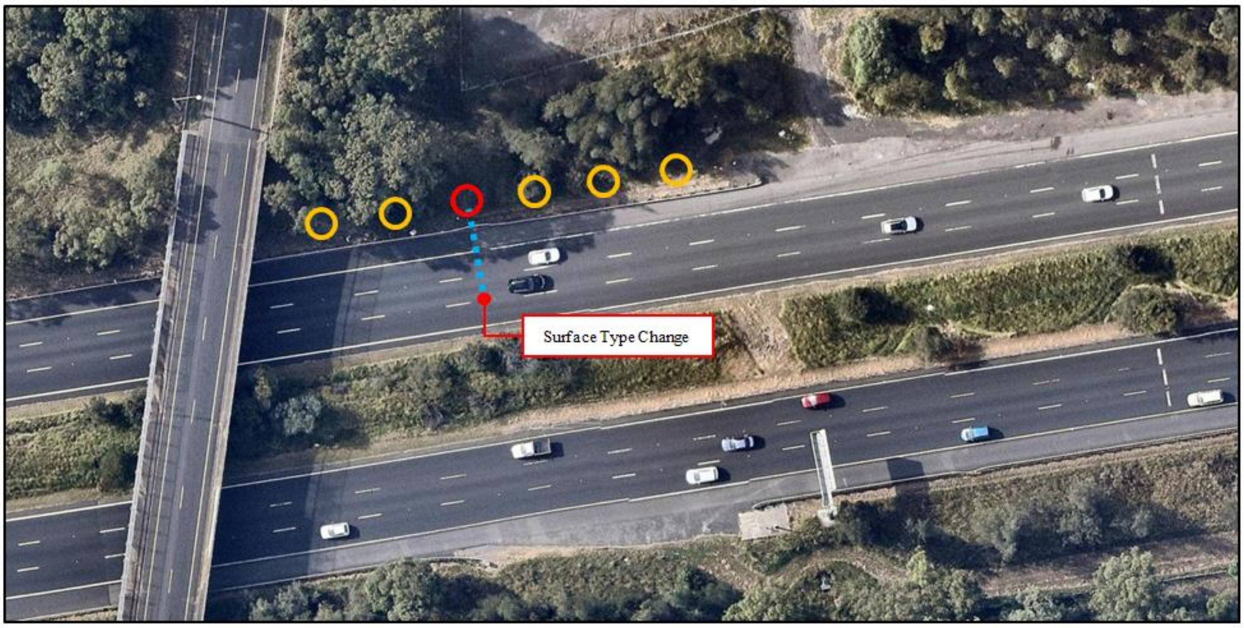

Figure 5: Roadside measurements

The noise loggers were processed to give an LAeq noise level for each location during the measurement period and this data is provided in Figure 6. Also provided in the figure are the corresponding OBSI measured surface corrections for the eastbound carriageway at each of the six noise monitoring locations for comparison.

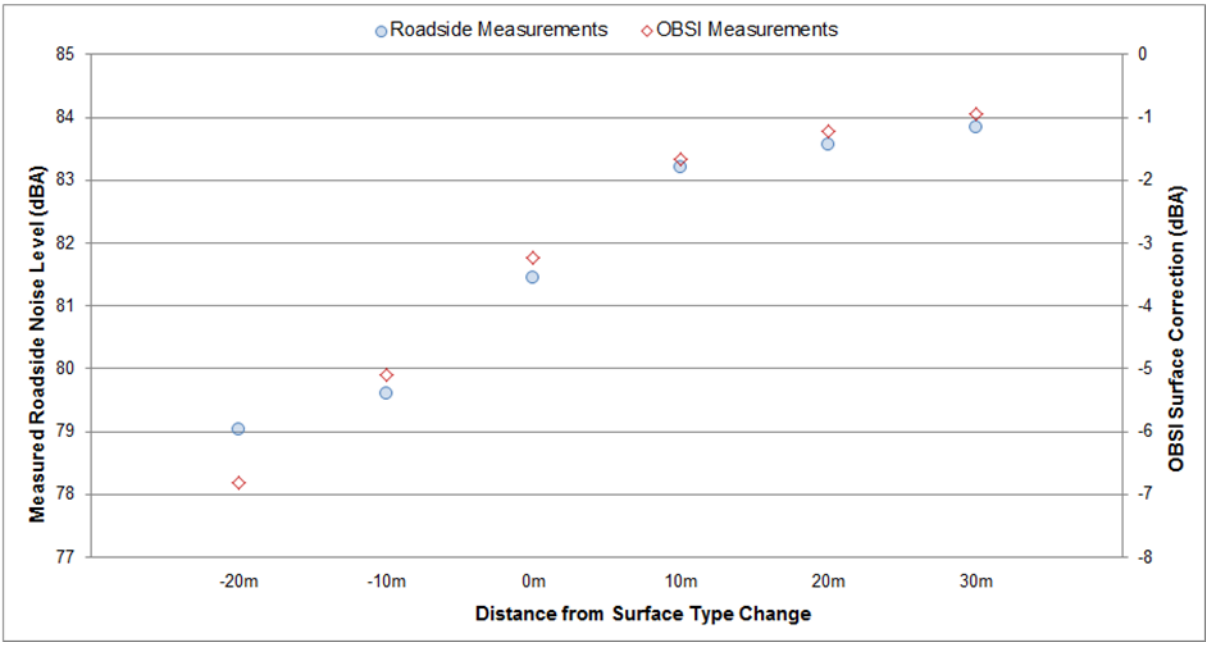

Figure 6: Measured roadside noise levels and OBSI road surface corrections at surface type change

Reference to the above shows that the OBSI measured surface corrections correlate extremely well with the measured roadside noise levels. The two data sets show an almost identical trend in change of measured noise levels at the -10 m to +30 m noise monitoring locations, with the roadside measured noise level at the -20 m location deviating slightly from the trend by around +1 dB. The marginally higher roadside noise level is likely attributable to the presence of the overpass to the west of this location (shown in Figure 5), which may have contributed additional noise due to reflections from the abutment and underside of the bridge structure. Reflections from nearby structures would not influence the OBSI measurements.

3.3 Results from Noise Modelling Using 'Standard' and OBSI Corrections

The noise modelling results using the 'standard' corrections in comparison to the OBSI derived road surface corrections are summarised in Table 2 and Figure 7.

Table 2: Noise Modelling Summary – 'Standard' vs OBSI Road Surface Corrections

Monitoring Location ID	Noise Level (dBA)				
	Measured	'Standard' Corrections		OBSI Corrections	
		Predicted	Difference	Predicted	Difference
1	59.6	61.3	1.7	60.8	1.2
2	69.1	72.5	3.4	72.0	2.9
3	77.3	77.8	0.5	77.3	0.0
4	57.7	60.2	2.5	58.9	1.2
5	78.0	74.5	-3.5	75.6	-2.4
6	77.3	74.9	-2.4	76.3	-1.0
7	61.4	59.9	-1.5	60.9	-0.5
8	64.1	65.8	1.7	64.0	-0.1
9	57.6	62.5	4.9	59.8	2.2
	Median		**1.7**	**Median**	**0.0**
	Average		**0.8**	**Average**	**0.4**
	Standard Deviation		**2.8**	**Std Deviation**	**1.7**

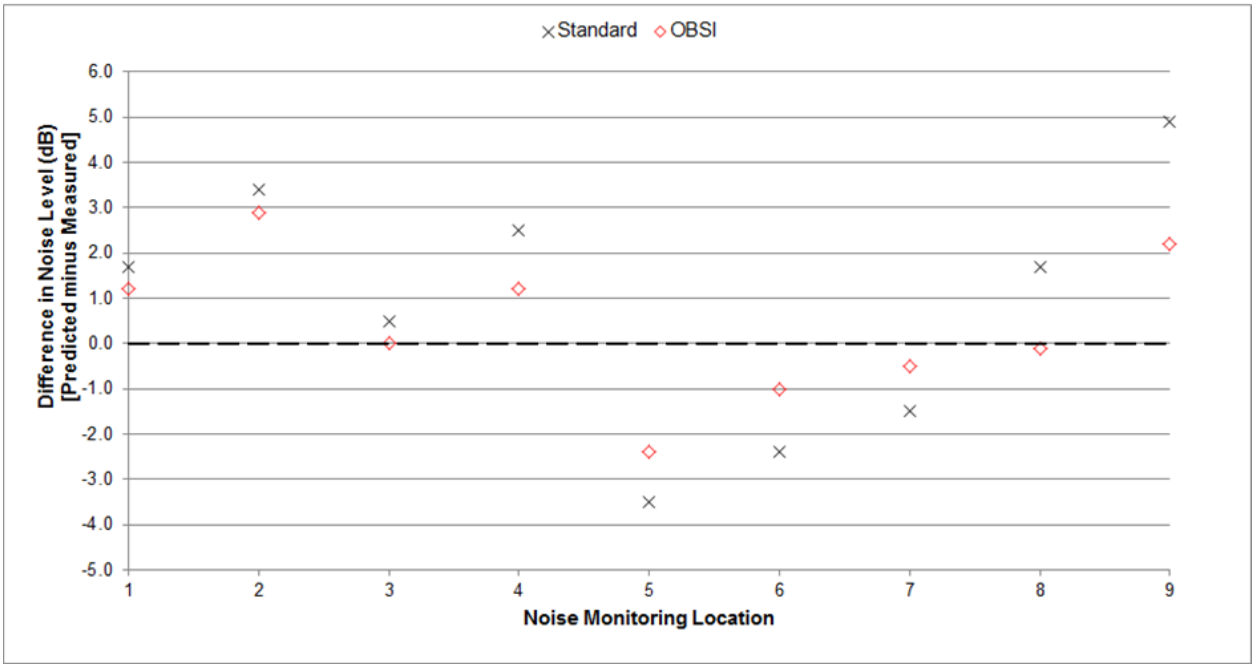

Figure 7: Noise modelling locations – 'Standard' vs OBSI road surface corrections

Reference to Table 2 and Figure 7 indicates that the use of OBSI road surface corrections has increased the accuracy of the noise model. The median error has been reduced from 1.7 dB using 'standard' corrections to 0.0 dB using OBSI corrections, with the average difference being reduced from 0.8 dB to 0.4 dB. The standard deviation of the dataset has also been improved from 2.8 dB to 1.7 dB. The predicted noise level at all nine noise monitoring locations is closer to the measured level using the OBSI corrections.

Noise models will commonly produce acceptable errors of around 2 dB (ENMM, 2001). However as this study indicates, roads which have particularly worn or old pavement surfaces can have significantly higher noise emissions than the 'standard' road surface corrections allow for. Similarly, new sections of low noise pavement can perform significantly better than is commonly assumed. With consideration of this through the use of the OBSI measured road surface corrections, the majority of the predicted noise levels for this study are now within (or significantly closer to) the accepted accuracy of noise modelling.

It is noted that Location 2, which is an outlier with the highest positive difference between OBSI predicted and measured noise levels, had very dense foliage blocking line-of-sight to a significant portion of the motorway and was not accounted for in the noise model. This may explain the over-prediction at this location in both noise modelling scenarios.

4. Conclusion

Road surface corrections have been measured using the SLR 3D printed OBSI system for the eastbound and westbound carriageway of a test section of the M4 Motorway. The OBSI road surface corrections have been applied to a noise model and compared to the use of 'standard' road surface corrections. The noise predictions in both scenarios have been referenced to noise monitoring data at nine locations within the study area.

The results of the modelling show that the predictions which make use of the OBSI road surface corrections correlate better with the measured noise level data when compared to the scenario using 'standard' corrections. The OBSI corrections were found to improve both the median error and the standard deviation of the dataset.

Based on this assessment the following future step is envisioned:

- At this stage the reference DGA surface correction has been estimated from the currently available data. SLR therefore propose to undertake OBSI measurements on a statistically relevant sample of DGA surface types in conjunction with controlled passby tests to define the reference DGA level from which all road surface corrections can be derived.

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