Environmental noise mapping using measurements in transit

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Abstract

Due to the ever increasing level of environmental noise that the EU population is exposed to, all countries are directed to disseminate community noise level exposures to the public in accordance with EU Directive 2002/49/EC. Environmental noise maps are used for this purpose and as a means to avoid, prevent or reduce the harmful effects caused by exposure to environmental noise. There is no common standard to which these maps are generated in the EU and indeed these maps are in most cases inaccurate due to poorly informed predictive models. This paper develops a novel environmental noise monitoring methodology which will allow accurate road noise measurements to replace erroneous source model approximations in the generation of noise maps. The approach proposes the acquisition of sound levels and position coordinates by instrumented vehicles such as bicycles or cars or by pedestrians equipped with a Smartphone. The accumulation of large amounts of data over time will result in extremely high spatial and temporal resolution resulting in an accurate measurement of environmental noise.

1 Introduction

In 2000, more than 44% of the EU population (approximately 210 million people) were regularly exposed to over 55dB of road traffic noise, which is potentially dangerous to health [1]. Additionally it has been estimated that these levels of exposure result in annual financial losses of between 0.2 and 2% of the GDP [2]. To address the situation the EU issued Directive 2002/49/EC relating to the assessment and management of environmental noise [3]. The Directive calls for the development of strategic noise maps and action plans for major roads, major railways, major airports and agglomerations that exceeded certain threshold values. The first phase of the mapping process is now complete and Member States should be in the process of implementing the associated action plans. However, the Directive sets out a cyclical process whereby strategic noise maps have to be developed every 5 years.

A noise map is a graphical representation of noise in a selected area. Noise maps may be developed using a variety of different techniques and results may be displayed using a variety of different noise indicators. For example, in the past the UK used the L_{10} index, which represents the level of noise exceeded for 10% of the time, while France used the L_{eq} indicator, which is an energy based index. This meant that different studies could not be compared or combined. To introduce a level of uniformity in the process, the EU developed two universal indicators L_{den} and L_{night}. L_{den} is the day-evening-night indicator and provides for the assessment of overall annoyance while L_{night} is used as a sleep disturbance indicator. However, while all noise maps are now developed in terms of L_{den} and L_{night} there remains significant concern over the use of different calculation methods across Member States.

A wide variety of calculation methods may be used in the development of a noise map. For the first phase of noise mapping, seven different calculation methods were used to assess road traffic noise from major roads across Europe [4]. Several studies have highlighted the impact this will have on results and ultimately the results of studies made with different prediction methods may not be directly compared or combined [5]. Separate to the chosen calculation method, the choice of software package may also influence results as several authors have observed that different software packages applying the same standard may also yield significantly different results [5, 6, 7].

Additionally, one must consider the large amount of input data required to develop a noise map. Detailed datasets describing the characteristics of the source and a digital representation of the propagation path are required to accurately predict noise levels at various positions from the source. It is inevitable that a complete set of input datasets will rarely exist. It has been noted in the past that the accuracy of any noise map will be directly limited by the accuracy of the input data [8].

It would certainly appear that strategic noise maps should be used for strategic purposes and some degree of inaccuracy in results must be accepted. The EU has tried to provide a solution in the shape of a common European assessment procedure. However, initial reports suggest this is quite complex and relies on even more detailed input datasets [9]. If one agrees that the accuracy of a noise map is limited by accuracy of the input data it would seem that there is no value in investing a great deal of time and effort into a complex and computationally challenging calculation model. An alternative is required.

Noise calculation methods are generally constructed in a similar manner, i.e. they will have two distinct parts;

i) a source model and

ii) a propagation model.

The propagation models are well defined and most models will agree on the rate and types of noise attenuation over propagation from the source. The main issues, in terms of accuracy, arise from the modeling of the source. One should note that the source model is also the most difficult to assemble in terms of detailed input datasets. For example sign posted speed limits rather than actual speeds are often used along with average estimates for the percentage of heavy vehicles in the flow. If an improved source model was available for use then significant savings in terms of time and collection of input variable would result. This paper aims to develop such a model by utilising the possibility of taking noise measurements in transit which could then form the basis of the source model in the development of a strategic noise map.

1.1 Objective

The objective of the current paper is to investigate the possibility of acquiring noise measurements in transit through various transport modes. This paper primarily focuses on the case of a pedestrian walking on a test street, but other transport modes, a bicycle and a car, are also considered. In each mode of transport a sound level meter, synchronised with a GPS unit log the position and noise level every second. It is hypothesized that measurements taken in transit will correspond with noise measurements taken in a static position acquired according to current standard practices. Finally the possibility of using the transit measurement method to develop a source model for strategic noise mapping exercises is discussed.

2 Current Practice

In Ireland and across Europe noise maps are generally made using predictive techniques and measurements are only made after calculations are complete. The purpose of these measurements is to validate results; however no uniform validation method has yet been developed or agreed upon. As such measurements are often performed as a token effort and offer no real benefit to the noise study. An alternative approach was adopted in Madrid where, following a detailed measurement campaign, the strategic noise map was developed primarily with the measured data. This was very much the exception to the norm.

2.1 Predictive Techniques

The most widely used method for predicting road traffic noise in Ireland is the UK's CRTN method [10]. This method was released in 1988 and replaced the previous method which was developed in 1975 [10]. The revision was carried out by the Transport Research Laboratory (TRL) and the Department of Transport in the United Kingdom. This publication includes a method which may be used to determine the noise source emission levels of road traffic due to the nature of its composition along with a method to determine how the noise is attenuated as it propagates away from the source. In this method the road is treated as a line source. Instead of point to point propagation, the angle of view of the road becomes an important factor in calculations. Additionally, this method does not calculate attenuation in terms frequency bands, but rather offers an overall A-weighted result.

In a critical review of road traffic prediction models, Steele [11] notes that CRTN is distinguished by its extensive use of curve fitting between empirical data even when this was known not to conform to theory. This greatly simplifies calculations albeit with the concomitant loss of validity. Predicted noise levels are expressed in terms of the L_{10} index and it is therefore quite different to the L_{den} and L_{eq} indicators. As such, a conversion factor is required to change results obtained from the CRTN model to satisfy the Directive. This conversion was initially developed from a regression relationship established between L_{eq} and L_{10} by TRL [12] in the UK and was subsequently adapted to an Irish scenario [13].

However, the EU Directive recommends a number of standards to be used by Member States who have no national computational method or Member States who wish to change their computational method. The recommended method for road traffic noise, XPS 31-133, has previously been used by the authors in the course of academic studies. XPS 31-133 was published in 2001 and describes the same calculation procedures as NMPB-Routes-96. It refers to the "Guide du Bruit" (1980) as a default emission model for road traffic noise calculations. The procedure for calculating noise levels in the environs of a road involves dividing the road into separate point sources and as such relies on point to point calculations. A flow of cars along a road is modelled as a number of line sources which are then broken up into point sources. The calculations are valid to a distance of 800m from the road. Results are presented in a form of the L_{eq} indicator and as such it is straightforward to calculate L_{den} and L_{night} levels. Meteorological conditions are accounted for through the use of an index accounting for the level of occurrence of conditions favourable to noise propagation. The influence of the frequency of the noise on propagation is accounted for using an octave band analysis approach. A comparison was recently drawn between the emission data for roads in Guide du Bruit and the German RLS 90 and the Austrian RVS 3.02. This study found that the data in Guide du Bruit was as good as these methods, both of which are still in use today [14].

As regards input datasets, WG-AEN released a good practice guide for noise mapping [15], which outlines various assumptions that may be introduced to the mapping process and provided estimates on the impact these assumptions will have in terms of accuracy. These guidelines have been widely used for the first phase of noise mapping.

2.2 Measurement Techniques

The CRTN method also includes a method for measuring road traffic noise. The CRTN measurement method was originally intended to be used to determine the level of noise at the source when traffic conditions fell outside the scope of the prediction method i.e. the "basic noise level". However, it has since become the *de facto* measurement standard to determine the baseline noise environment in Ireland particularly in the development of Environmental Impact Assessments for Road schemes. The Irish National Roads Authority makes reference to this method in their "Guidelines for the treatment of noise and vibration on national road schemes" [16].

The ISO 1996-2 (1983) standard is also recommended for use in the NRA guidelines. The standard has been revised since the 1983 version and includes an uncertainty analysis tool; however the revised standard has not yet been recommended for use by any Irish authority.

3 Proposed Technique

The proposed technique is based on the underlying principle associated with using the shortened CRTN measurement method i.e. to use measurements to determine the level of noise at the source for situations where the traffic conditions are not applicable to the predictive method. Instead of predicting the noise level at the source, the source model is determined by measurement. This measured source model is then used in conjunction with the same theoretical prediction model enabling a noise map to be developed.

In the context of the EU Directive such an approach is not unprecedented. In 2002 a noise map for the agglomeration of Madrid was made based on 4395 measuring points. However this measurement based noise map was very expensive and complex to produce. A new system has since been initiated in Madrid to comply with the Directive in a more effective manner, known as the SADMAM system. The main goal of SADMAM is to produce fast and cheap measured noise maps that combine both long term and short term noise levels along with a realistic propagation model. Measurements are generally taken by mobile noise monitoring terminals, in the form of a SMART car with a microphone fitted to a telescopic pole (Figure 1), over short time periods at strategic locations in the city. These measurements are used to determine source strengths that are then fed into a prediction model that creates the map. The source strengths are determined by measuring noise at receiver positions and using an inverse method approach to determine the noise levels at the source. It was observed that if there are several sources, the sound power level of the various sources become more difficult to determine. This problem is solved by careful choice of the receiver positions based on knowledge of the behaviour of the different sources in the area [17].

Figure 1: Mobile Monitoring Station, Madrid

A similar approach was also adapted to map the main campus of Pusan National University, in the Republic of Korea [18]. Again the maps produced were based on source strengths determined from measured data while it was noted that the quality of the map depended on the number and accuracy of the measured data.

3.1 Test Procedure

It is important to note that in Madrid the SMART cars park and stay stationery during the measurement period. The proposed method in this paper is to take measurements in transit, assessing a variety of transportation modes: walking, cycling and driving. As will be discussed in the results, the noise level at the source was determined initially by analysing noise measurements, taken in transit, by a test pedestrian (the test subject) traversing the streets under examination. The subjects' position and the noise level were logged every second via a GPS system synchronised with a sound level meter (and a noise dosimeter for the pedestrian case). Microphones were positioned at waist level and shoulder level, Figure 2. Thus, instead of measurements only acquiring data at fixed positions, data was captured at one second intervals over a range of locations along the route. For a single data set, *viz*. the acquisition of time and location for a single journey by a pedestrian/bicycle/car, a high spatial resolution can be obtained (ref. dataset 1 in figure 3) compared to a single fixed location measurement, as performed in accordance with the CRTN/ISO 1996 procedures. Through the assembly of data over many such journeys, very large amounts of data can be gathered for any one location - ref. dataset 2 in figure 3. The result in the accumulation of this data will be information gathered at both a high temporal and spatial resolution.

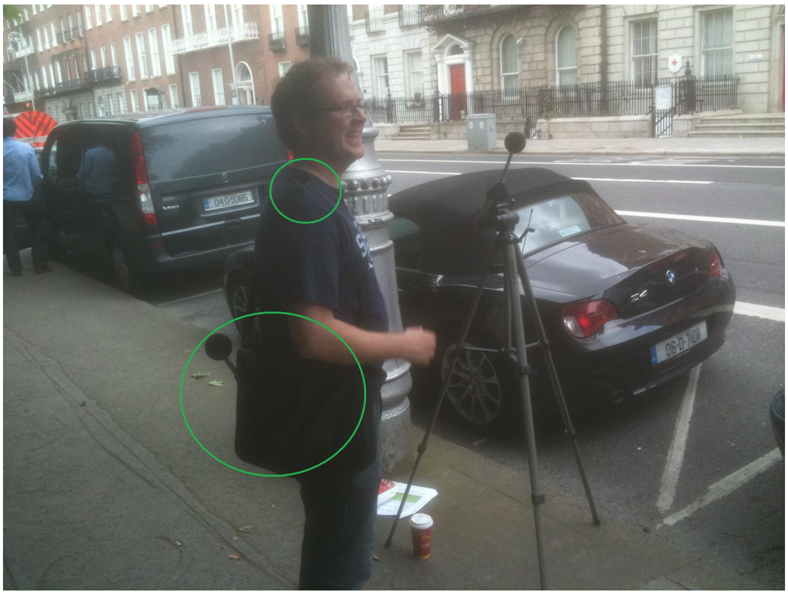

Figure 2: Test Subject. Note positioning of shoulder and waist microphones.

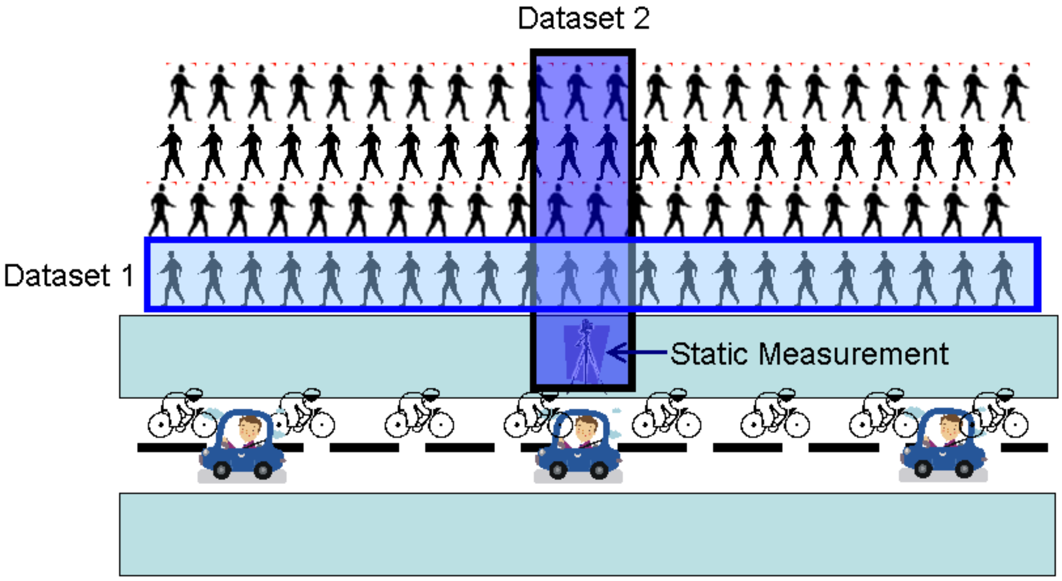

Figure 3: Schematic showing the novel environmental noise monitoring methodology.

As a reference condition, a noise meter also logged noise levels in accordance with ISO 1996, i.e. the current standard method, at a fixed position in the centre of the test street at a measurement height of 1.5m. This reference microphone was placed on the edge of the footpath (so as not to impede pedestrians) while the test subject generally walked in the centre of the footpath. As such when analyzing results, it may be expected that the reference level may be slightly higher than the transit level, due to positioning microphone closer to the source.

Measurements taken in transit are taken by a variety of means depending on the mode of transport. Microphones mounted on a pedestrian, a bicycle and a car were all examined for this initial test. The following situations were analysed:

- A noise dosimeter logging the noise level every second was placed on the test subject while walking on the test street
- In addition to the noise dosimeter, the test subject also carried a Svan957 sound level meter at waist height.
- When cycling the Svan957 sound level meter was placed in the front basket fixed to bicycle.
- Finally, measurements were taken on the roof of a car travelling in the flow of traffic.

Detailed considerations of each method described above are presented in sections 4 and 5.

3.2 Test Location

The test location was Merrion Square, one of the largest Georgian Squares in Dublin and adjacent to Trinity College Dublin, Ireland. Figure 4 presents a map of the test area. The Garden of Leinster House (the Irish parliament) is to one side of the square while the other three sides consist of Georgian houses which are primarily used as offices. The square is surrounded by two major roads (N11 and R118) and two relatively minor roads.

Figure 4: Map of Merrion Square (the test site). Note position of major roads N11 and R118

3.3 Test Matrix

This work describes the initial testing of the proposed mobile measurement methodology. A number of test cases were examined. It is hoped that these test cases will identify key issues associated with taking measurements in transit and provide a robust testing methodology for the future.

1. In theory measurements taken in transit should correspond to levels at the fixed measurement position when the test subject is in the region of the fixed position. The first set of tests investigates if this is the case.
2. For strategic noise mapping it is generally assumed that noise levels are constant over the length of the test road, i.e. measurements at the fixed position represent the noise level of the road under examination and this noise level is constant along the full length of the road. We investigate if noise levels taken at all positions over the road correspond to the level recorded at the static position.
3. The positioning of the microphone in transit may have an impact on results. Results from a dosimeter placed on the test subjects shoulder with a sound level meter carried at waist height are compared to examine this impact.
4. The direction of travel is also a consideration as when the test subject walks from East to West the microphones are shielded by the test subject’s body whereas, when travelling in the opposite direction the microphones more exposed to road traffic.
5. Finally a preliminary investigation of other modes of travel is explored. This involves mounting the microphone on a bicycle and a car.

4 Results

In order to process results all devices were synchronised prior to testing. Discrepancies in GPS results were noted in terms of recorded co-ordinates. When the GPS device has a poor connection with satellites, which may happen in a city centre due to tall buildings etc., errors in results may arise. The positional accuracy of the GPS unit may also impact results. However, for the most part, GPS co-ordinates, coupled with the knowledge of the test subject, are reliable enough to determine the approximate position on the road at any given second. This is an issue which will need to be addressed were the method to be widely adopted. However a more sophisticated GPS unit with an improved antenna may yield a simple solution.

Sections 4.1 - 4.6 address each item in the test matrix defined above in section 3.3. For comparison purposes the overall noise level recorded at the fixed position using the standard methodology, i.e. the reference noise level was 68.3 dB(A) $L_{eq,\ 1\ hour}$ with a standard deviation 6.76 dB(A).

4.1 Test 1 – Variation of noise level over road length

The objective of this test was to quantify how the noise levels varied over the length of the road. For the purposes of strategic noise mapping it is generally assumed that the noise level is constant over the length of the road. This is usually because computation tools and prediction methods assume a road as a continuous source and do not allow for various discontinuities such as areas of acceleration or deceleration along the road. While it is accepted that in reality these areas exist, over time it is assumed that the noise will average to a relatively constant level.

In order perform this test the mobile measurements are divided into separate ‘paths’ where each path comprises of those measurements taken over one length of the road. Figure 5 shows how the noise levels vary over the course of one path i.e. measurements taken in transit as the test subject walks from East to West along the test route (R118 – coloured yellow in Figure 4) .

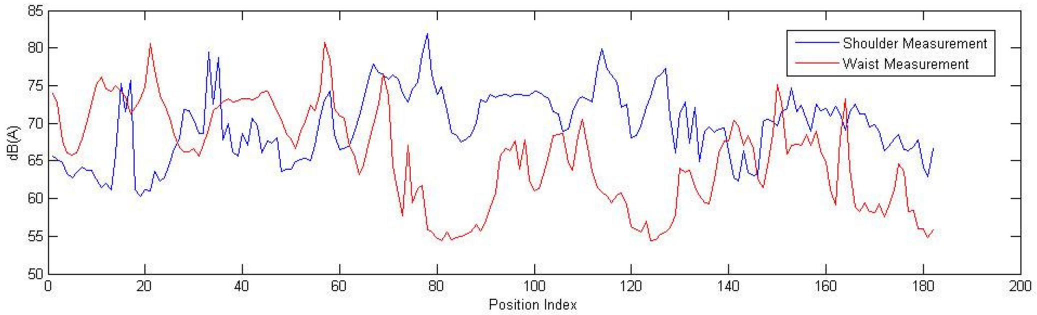

Figure 5: Variation of Noise Level over Path 1

From Figure 5 we see that the difference between measurements taken at shoulder height and waist level vary across the length of the street. This is discussed in more detail in section 4.3. Table 1 presents the equivalent noise level for each path and compares it to the static measurement recorded during the same time period.

	Direction	L_{eq} from Transit (Shoulder)	L_{eq} from Transit (Waist)	Static L_{eq}	Static - Transit (Shoulder)	Static - Transit (Waist)
Path 1	E to W	72.1	69.8	68.3	-3.8	-1.5
Path 2	W to E	69.2	65.9	68.2	-1	2.3
Path 3	E to W	70.1	66.4	68	-2.1	1.6
Path 4	W to E	69.2	68.5	69.2	0	0.7
Path 5	E to W	70.7	66.4	66.7	-4	0.3
Path 6	W to E	68.5	66.2	67.3	-1.2	1.1
Path 7	W to E	67.2	65.6	68.6	1.4	3
Path 8	E to W	71.6	70.9	69.3	-2.3	-1.6
Path 9	W to E	69.9	64.7	67.7	-2.2	3
Path 10	E to W	69.4	67.6	68.5	-0.9	0.9
Path 11	W to E	69.4	66.4	69.3	-0.1	2.9
Path 12	E to W	68.6	65.9	69.1	0.5	3.2
Path 13	W to E	68.3	67.8	67.8	-0.5	0
Path 14	E to W	71.3	67.9	69.1	-2.2	1.2
Mean		*69.7*	*67.1*	*68.4*	*-1.3*	*1.2*

Table 1: Comparing static measurements with measurements taken in transit over length of road

On average the L_{eq} measured in the static position over the complete path length is 1.3 dB (A) less than the transit measurement taken at shoulder height and 1.2 dB (A) greater than transit measurement taken at waist height.

4.1.1 Average overall variation over complete road length

Figure 6 shows the average noise level over the complete path of the road. It may be observed that measurements taken at shoulder height generally yield higher results than measurements recorded at waist level, up to the last quarter of the path. One possible reason for this is that cars are parked along the test road except at the ends. The parked cars may offer increased shielding at waist level. When this shielding is removed the two measurements begin to agree. It would appear from these results that, in general, the noise level does not significantly change over the length of the road, particularly when the extra shielding of parked cars is removed.

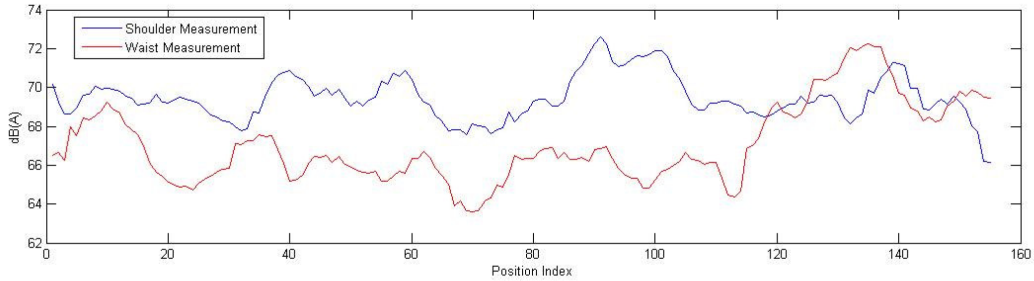

Figure 6: Average overall variation of Noise Level over complete Road Length

4.2 Test 2 – Comparing static measurements with mobile measurements

The objective of the first test was to determine if measurements taken in transit corresponded to levels recorded at the fixed position when the test subject was in the region of the fixed position. A buffer zone of varying size was established around the fixed position and the noise data acquired from measurements taken in transit within each buffer zone were compared to the fixed measurement results. Over the course of the test period 23 points were logged with 2m of the static position, 116 points within 5m and 296 points within 10m of the reference position. Table 2 below presents the results of each test.

	Time	**L_{eq}**	**Time**	**L_{eq}**	**Time**	**L_{eq}**
Reference "True" Level	*1 hour*	*68.30*	*1 hour*	*68.30*	*1 hour*	*68.30*
	Buffer 2m		***Buffer 5m***		***Buffer 10m***	
Static Level	23s	68.0	116s	69.3	296s	70.6
Transit Level (Shoulder)	23s	68.5	116s	69.4	296s	69.1
Transit Level (Waist)	23s	64.0	116s	66.7	296s	66.5

Table 2: Comparing static measurements with measurements taken in transit in region of static position

It is immediately evident that measurements taken at shoulder level yield results approximately 3 to 4dB greater than measurements taken at waist level but both sets of results yield similar results to the static position and the impact of the buffer zone does not appear to significantly impact the accuracy of results.

4.3 Test 3 – The impact of the mobile transducer's mounting location

In the previous tests it is noted that significant variation in results is recorded depending on the positioning of the microphone. A dosimeter was used to measure noise levels at shoulder level while a sound level meter carried in a satchel was used to measure noise levels at waist height. The positioning of the transducer will have a significant effect on results. Studies in the past have shown that placing a microphone on a person's body can effect measurements by anywhere from an A-weighted sound level of -1 to +5 dB (A) [19]. Additionally by placing one transducer lower than another, additional screening was offered at some points along the streets from parked cars causing a discrepancy in the results.

4.4 Test 4 – The impact of the direction of travel

In the previous tests it is noted that significant variation in results is recorded depending on the positioning of the microphone. The direction of travel was also investigated to see if one direction yielded different results to the other, as the microphones will be shielded by the test subject's body in one direction and not in the other.

West to East	Shoulder – Waist	Static - Shoulder	Static - Waist
Path 2	3.3	-1	2.3
Path 4	0.7	-0.1	0.7
Path 6	2.3	-1.2	1.1
Path 7	1.5	1.4	3
Path 9	5.3	-2.2	3.1
Path 11	3	-0.1	3
Path 13	0.5	-0.5	0
Mean	*2.4*	*-0.5*	*1.9*

Table 3: Difference in measured results when test subject was walking from West to East i.e. microphones were shielded from the road by subject's body

East to West	Shoulder – Waist	Static - Shoulder	Static - Waist
Path 1	2.3	-3.8	-1.5
Path 3	3.7	-2.1	1.6
Path 5	4.3	-4	0.3
Path 8	0.6	-2.3	-1.7
Path 10	1.8	0	0.9
Path 12	2.7	0.5	3.2
Path 14	3.5	-2.2	1.2
Mean	*2.7*	*-2.1*	*0.6*

Table 4: Difference in measured results when test subject was walking from East to West i.e. the test microphones were exposed to the road.

Table 3 presents results recorded when the test subject was walking from West to East i.e. microphones were shielded from the road by subject's body. It may be expected that these results would include a shielding effect from the test subject's person. On average shoulder measurements results were 0.5 dB greater than the static measurements while static measurements were 1.9 dB greater than measurements taken at waist level. When the test subject walked in the reverse direction and microphones were most exposed to the road, the shoulder measurements results were 2.1 dB greater than the static measurements while static measurements were 0.6 dB greater than measurements taken at waist level. Assuming static measurements as a reference, it would appear that the subjects head offered approximately 1.5 dB(A) shielding while the subjects body offered approximately 1.3 dB(A) shielding.

4.5 Further Tests

All tests described above consisted of a test subject walking on the footpath adjacent to a major road (the R118). Further tests were also performed to account for a number of additional factors. These tests involved the data gathering over the entire perimeter of Merrion Square. The results of these supplementary tests are discussed in this section and test data are independent of those datasets described previously. Figure 7 displays the 'breadcrumb trail' logged by the GPS unit for these tests. To aid the reader each side has been labeled S1 to S4.

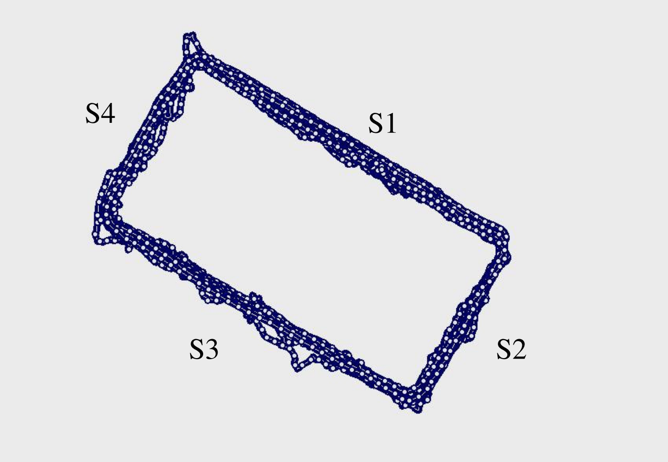

Figure 7: GPS co-ordinates of test subject walking around Merrion Square (dataset 2)

4.5.1 Minor Road vs. Major Road including bicycle tests

Several tests were completed to encompass both a busy road and a relatively quite road. These results are presented in Table 7 and 8. Also displayed are results logged around Merrion Square from a bicycle. The sound level meter was mounted on a bicycle using the front carrier basket. While cycling the bicycle the test subject noticed some noise from the bicycle itself. This extraneous noise would need to be removed for future tests but this could be achieved with some general maintenance. When one examines the GPS co-ordinates presented in Figure 7, (the 'breadcrumb trail') for each path, the effect of travelling by bicycle is evident; less sample points are recorded over the length of the road.

Side	Path	Mode	Static L_{eq}	Transit L_{eq}	Difference
S3	Path 1	W	67.3	67.7	0.4
	Path 2	w	67.3	78.5	11.2
	Path 3	w	64.0	59.1	-5.0
	Mean		*66.2*	*68.4*	*2.2*
S3	Path 4	c	67.7	64.6	-3.2
	Path 5	c	67.1	67.3	0.2
	Path 6	c	67.0	62.8	-4.3
	Path 7	c	63.5	72.8	9.2
	Path 8	c	68.2	71.7	3.5
	Mean		*66.7*	*67.8*	*1.1*

Table 7: Comparing measurements taken in transit by means of walking (w) and cycling(c) with static measurements for the same time periods on the southern quiet test road – S3.(Test Data

Side	Path	Mode	Static L_{eq}	Transit L_{eq}	Difference
S1	Path 1	w	64.43	X	X
	Path 2	w	65.76	66.56	0.8
	Path 3	w	63.25	67.95	4.7
	Mean		*64.5*	*67.3*	*2.8*
S1	Path 4	c	69.18	67.01	-2.17
	Path 5	c	72.37	69.31	-3.06
	Path 6	c	66.23	68.59	2.36
	Path 7	c	65.54	74.03	8.49
	Path 8	c	75.43	75.35	-0.08
	Mean		*69.8*	*70.9*	*1.1*

Table 8: Comparing measurements taken in transit by means of walking (w) and cycling(c) with static measurements for the same time periods on the northern busy road - S1 (dataset 2)

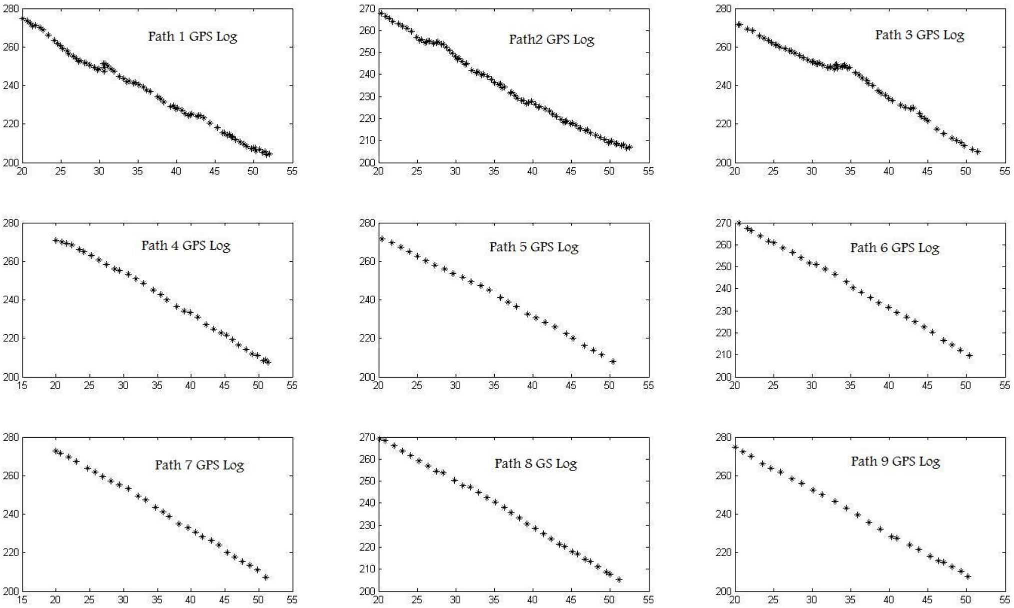

Figure 8: Comparing GPS co-ordinates logged by the pedestrian and bicycle

4.5.2 Acquiring data with a car

The final set of tests involved mounting microphones to the roof of a car (Figure 9). The car drove on the selected streets and logged position and noise level every second. Such a test involves a number of factors that must be considered including the orientation of the microphone, the location of the microphone and the possible use of a directional microphone. Further tests will be required to address each of these issues. However the initial tests also highlighted a number of other issues associated with acquiring measurements from a vehicle in transit:

- The primary issue that needs to be addressed is flow noise; that is the noise arising from wind impacting on the diaphragm of the microphone. Further research is required to address this issue but solutions such as shielding the microphone from the wind, or conditioning out the wind noise are being investigated.
- The noise of the vehicle itself must be accounted for. This could be solved by using the vehicle itself to shield the test microphones, alternatively an electric car could prove beneficial

Figure 9: Microphones mounted on roof of car i) oriented upwards and ii) orientated directly into the flow.

Figure 10: The project team with car and static microphone.

5 Future Work

This initial investigation into taking measurements in transit highlights a number of potential issues associated with the method. The main issues of note may be summarised as:

- Accurate GPS logging will be necessary
- The positioning of the microphone (height and orientation with respect to the road) should be uniform in order to produce repeatable results
- Further tests should be carried out in order to develop a large database with reliable results
- When using a bicycle the bicycle should be maintained in order to minimise noise from the bicycle itself and again the positioning of the microphone should be uniform. The most appropriate position should be determined after detailed study
- Further tests are required to address the many issues associated with acquiring data from a car in transit.

6 Conclusions

Competent authorities must develop noise maps to effectively manage environmental noise and these maps should reflect as accurately as possible the actual scenario. However a balance must be reached between the complexity of computational procedures and the accuracy of final results. It has been shown that a number of computational simplifications will result in a noise map being computed in a fraction of the time while still maintaining accuracy. One such simplification may include determining noise levels at the source by means of measurement instead of predictions.

This paper has explored the possibility of taking measurements in transit through a variety of modes of transport. Initial tests involving a pedestrian walking on a city centre street suggests the methodology may be applicable. Further tests involving a bicycle and a car will be required in order to determine the optimal position for microphones and test arrangements.

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