Dalhousie University – Environmental Science

Community environmental noise and the built environment in two Halifax neighbourhoods

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1. ABSTRACT

A study of two Halifax neighbourhoods was conducted to examine the effect of the built environment and land use on levels of environmental noise during January and February of 2008. The study areas were identified using dissemination areas of the Canadian Census program, land use information, air photography and ground truthing. The first study area was a residential area consisting of two- to three-story single family homes and the second was a mixed-use region with apartment buildings, as well as commercial and institutional development. Study areas were gridded into six areas and a random sample point in each grid area was identified using ArcGIS. Each sample point was sampled four times over the 24-hour day, resulting in a total of 24 samples for each of the two areas, with one sample taken per hour. Study results demonstrate that the mixed-use area had statistically significant higher levels of environmental noise then the residential area. Study results were compared to health guidelines from the EPA and Italian Government and found to exceed the allowable limits.

2. INTRODUCTION

Human and community health are greatly affected by the built environment. The term "built environment" refers to the portion of the physical environment constructed by humans, for humans, and it includes buildings, roads, and other transportation systems, as well as open spaces like parks and sports fields (1). The structure and use of the built environment are linked to various types of negative health impacts, including cardiovascular and pulmonary disease, obesity, and asthma, as well behavioural impacts such as depression, stress and annoyance (1;2). Approximately 80% of the population of North America resides in an urban environment, and is exposed to various pollutants produced by human activities including environmental noise, particulate matter, vehicle emissions, and chemical runoff. Therefore the urban environment has become an important focus of current environmental, human health and epidemiological research.

Environmental noise, as with other types of anthropogenic area pollution results from the high population concentrations, correspondingly high concentrations of vehicles, and intense industrial and commercial development found in the urban environment. Main sources of environmental noise include road traffic, construction and public works, industrial and institutional activity, and social and economic activities (3;4). In the urban environment, these activities are brought into close proximity to the human population increasing exposure and possible health effects.

Environmental noise has been linked by epidemiological research to health outcomes including increased levels of hypertension and high blood pressure (5), lowered cognitive ability

(6), and increased occurrence of cardiovascular disease (7). Qualitative studies have shown that environmental noise is considered to be the most annoying of all types of urban pollution (3;8), interfering with enjoyment of daily activities and causing loss of sleep and rest. This can compel people to migrate to other cities or into less populated areas, like suburbs, contributing to urban sprawl and increasing environmental noise and other pollution.

Much environmental noise research is concentrated primarily on occupational exposures for the development of regulation. These regulations prescribe the amount of time workers are allowed to be exposed to specific sound pressure levels (SPL) and outline the type of noise protection workers are entitled to. Little work has been conducted into the relationship of environmental noise and the built environment and the resulting environmental noise.

Environmental noise is considered by the World Health Organization (WHO) to be any noise which is not occupation related, either indoor or outdoor(9). WHO identifies the main sources of indoor noise as ventilation systems, home appliances, office machines and neighbourhood activities. Outdoor sources of environmental noise include social noise, commercial and domestic noises, music, playgrounds, sporting events, pets and transportation infrastructure. Difficulties with the definition, measurement and control, as well as insufficient understanding about the health effects of noise on people, have resulted in an inability to effectively ameliorate environmental noise at levels potentially harmful to health (9).

As with many Canadian urban centres, Halifax, through the 2007 Regional Municipal Planning Strategy (RMPS), is planning to intensify urban development by combining land-use types to create mixed-use regions with a focus development into core areas. There are good reasons for densification of urban core areas. First, Halifax will require approximately 18 000 hectares of new residential development by 2010 if current projected growth rates continue (10). Second, continued urban sprawl will result in increased costs for the provision of municipal services including water and sewage piping, emergency services, as well as road development and maintenance.

Urban sprawl significantly impacts the physical environment of a city. Studies have shown urban sprawl to be implicated in soil loss (11), fragmentation and loss of local forest areas (12), as well as local arable land (13). Urban sprawl also influences human health through direct and indirect mechanism. For example, increased reliance on automobiles as a form of transportation has been shown to increase air pollution concentrations resulting in increased prevalence of cardiovascular disease (14). Automobile reliance has also been shown to reduce levels of physical activity which has led to increased prevalence of diabetes and levels of obesity (15-17). These issues make the planning strategy to intensify development in core areas very important for the health and sustainability of our communities.

Conversely, intensification of land-use can also have unhealthy effects on human populations and the environment. Several studies have identified areas of health concern that can result from increased urbanization which include social alienation and psychosocial health problems, increased risk of disease resulting from living in close quarters with populations of animal vectors, like rats and fleas, and increased exposure to pollutants like particle pollution and environmental noise (18-20). It is important to understand these health issues at both the planning and regulation level because while intensification is necessary for the health of cities and possibly the world, we need to understand how our actions will affect the human residents of the cities and properly protect their health and safety.

2.1 *Objectives and Scope*

The objective of this study is to sample and analyze environmental noise data characteristic to two distinct urban land uses. By examining levels of environmental noise in two forms of the urban built environment, the study provides information relevant to urban planners and public health professionals. The project is timely given that little is known about the potential for human health impacts arising from environmental noise as a result of current plans to intensify development of the urban core.

One of the study neighbourhoods is an older-style, traditional residential neighbourhood with few roads and predominantly free standing single family dwellings. The second study area is a modern-style neighbourhood which has a high road density, and mixed land-use including residential apartment buildings, commercial enterprises and first floor commercial development with residential development above. This study is one of the first to examine environmental noise in Halifax.

The scope of this project is limited to these two representative areas as it is not feasible to measure environmental noise across the whole of Halifax Regional Municipality (HRM) because of time and financial constraints. The project is also limited temporally as it focuses only on weekdays, and does not include seasonal influences. This study examines the complete

24-hour day in order to fully estimate the variation in the character and volume of environmental noise throughout the day and night.

3. LITERATURE REVIEW

Environmental noise has a documented impact on the health and well-being of individuals. Although research has traditionally been focused on occupational exposure (21), recent studies have examined the effects of environmental noise outside the work environment, including how it affects humans at the population level. The psychological and physiological effects of exposure to environmental noise include sleep loss, annoyance, hearing loss, cardiovascular problems, and depressed task performance (4-6).

Sound is comprised of alternating compressions and expansions of the medium through which the sound wave travels. The volume of the sound is expressed as a slight positive or negative deviation of atmospheric pressure, the greater the deviation the louder the sound, while the frequency of the cycle of alterations determines the pitch (4). The human ear can normally detect frequencies between 20 hertz (Hz) and 20 kilohertz (kHz); however this range can be affected by damage resulting from loud sounds or illness. A low frequency sound is heard as a deep hum, while a high frequency sound is heard as a squeak.

Sound is measured by comparing the logarithm of a given sound to a reference sound pressure, and is expressed on a logarithmic decibel (dB) scale. When assessing the impact of sound it is important to note that the difference between 60 dB and 70 dB is a ten-fold increase in volume and the impact of the sound will also be ten-fold greater (4). The human ear does not register sound equally on all frequencies, so the effects of sound on humans cannot be accurately assessed without weighting the measurements to reflect human hearing sensitivity.

A weighting system called A-weighting is used to adjust results in studies examining human impacts from environmental noise to better reflect human hearing [dB (A)] (4).

Environmental noise research is centred in a few regions across the globe, reflecting the local societal evaluation of the significance of the dangers and annoyance of environmental noise. The European Union and Hong Kong are two prominent areas of sound research, and both regions regulate environmental noise. Italy, for example, has environmental noise exposure limits set by federal legislation with identified acceptable levels of sound for given land-uses, for both daytime and night-time (22). Other cities, including San Francisco, USA (8), Hurghada, Egypt (23), and Valdivia, Chile (24) have also been studied in recent years, demonstrating the developing awareness of environmental noise and its impact.

A review of available documentation shows that Canadian interests lie primarily in the regulation of occupational noise and noise emitted from consumer goods. Powered equipment and vehicles must conform to federal regulations for levels of acceptable sound emission. For example, Schedule v.1 (Section 5) Noise Emissions - Standard 1106 of the Motor Vehicle Safety Regulations provides allowable interior and exterior sound levels for different classes of vehicles. However these regulations do not apply to “after sale” conditions, such as modified mufflers. Federal regulations also control noise from inter-provincial transportation systems including trains, highways, aircraft, and waterways. As well there are provisions for national occupational health and safety guidelines found in the Canada Labour Code, Part II, (R.S.C. 1985, c. L-2) Canada Occupational Safety and Health Regulations, (SOR/86-304) Section 7.4(1)(b).

Provincial governments regulate the operational noise levels of equipment, vehicles and other commercial goods, and produce environmental noise guidelines for land-use types and for provincial roads, as well as setting occupational health and safety standards under the Occupational Health and Safety Act (S.N.S. 1996, c.7). Municipal governments are responsible for environmental noise regulation based on disturbance, with bylaws controlling noise-emitting events. Examples include the Halifax Regional Municipality (HRM) By-Law N-200 and the City of Vancouver By-Law no. 9344.

Environmental noise, unlike many other types of pollution, is dependent on local physical conditions. Many factors including development planning, the structure of the built environment, population density, as well as local habits and culture can determine how dangerous environmental noise is to the local population (25). The World Health Organization (WHO) has set maximum values for environmental noise with respect to human health but these do not take into account local factors which can affect environmental noise.

3.1 *Sampling Strategies*

Ambient environmental noise studies assess noise within a defined spatial region, such as a city, and describe the cumulative exposure to residents. Three general strategies for investigating environmental noise in an urban environment include sampling by grid, road classification, and studies that are restricted to either a source or receptor of environmental noise (26). The grid sampling method is the system currently recommended by the International Standards Organization (ISO) for ambient environmental noise studies (27). This method uses an evenly distributed sampling grid, resulting in good spatial distribution data. The classification sampling system uses road type or land use classes to break a city up into study areas. Average noise values are assigned to all areas of that classification type. Classification studies are the most economical in terms of cost and labour and present data in an easy to understand format. Studies of these types use a few study points to characterize each identified class, generating a set of average values which can be applied for all areas of that type and are generally used for creating thematic noise maps. These advantages make grid sampling and classification studies the ones most commonly used by cities and noise consulting firms.

Source studies examine either a physical point source of environmental noise, like an airport (28) or a vector source, like a road network (29). Source studies focus on the planning and development of new infrastructure to limit the exposure of nearby residents to harmful levels of sound, or on planning noise abatement procedures (23;29). Source studies are conducted by examining the peak levels of sound produced by the target source and comparing them to appropriate guidelines.

Receptor study designs examine the effect of environmental noise on a target receptor by studying multiple cohorts exposed to different amounts of environmental noise (5). These designs usually perform an assessment of the exposure levels of a target group. Health researchers commonly use this type of study to examine the long-term impacts of noise on human health (29).

3.2 *Sampling Periods*

The written literature has little agreement on the appropriate frequency and duration to sample environmental noise. Sampling frequencies and approaches vary greatly among studies, and include 15-minute measurements every two hours (22), daytime-only assessment (25), day and night measurements(30), and continuous assessment (31). Sommerhoff et al. (24) and Ng et al. (32) used a three-period assessment, dividing the 24-hour clock into three periods (day, evening and night) but differed slightly in their period start times and sample lengths. This study used a modified version of the three-period assessment method, and incorporated refinements discussed by Ng et al. (32) for improving the statistical accuracy of the testing.

A three-period division of the day may not be sufficiently accurate for a full assessment of the quantity of environmental noise produced in a day. Daytime periods should be subdivided into two sections, morning and afternoon, resulting in a statistically valuable improvement in assessment quality (32). Moreover, only the first or last two hours of the night period should be sampled so as to include the times of highest environmental noise production. Dividing the night periods into two sample periods has not been shown to have a statistically-significant effect on the quality of the data, and may increase resident disturbance (32).

3.3 *Health Related Values*

Health standards for environmental noise are developed by various organizations including WHO, the (European Union) EU and the US Environmental Protection Agency (EPA) as well as by specific countries or cities. These values consist of sound levels that are acceptable during parts of the day commonly divided by the dominate usage of the area. Values are based primarily on sleep disturbance and acceptable annoyance levels (33;34).

The EPA uses two time periods, day (07:00-22:00) and night (22:00-07:00) to define allowable environmental noise levels and classes of land use in an effort to provide guidelines that reflect usage and the local population base. Urban residential areas have a daytime recommended maximum exposure of 52 dB (A) and a night-time value of 45 dB (A) while a predominantly industrial area has a limit of 70 dB (A) for both night and day (table 1) (33). Italy is one of the few countries that have put noise exposure limits into legislation. They have used the same general procedure as the EPA and defined day (06:00 – 22:00) and night (22:00-06:00) periods which have permissible limits for the equivalent continuous sound level in dB (A). Residential areas in the Italian legislation are limited to 55 dB (A) and 45 dB (A) at night, while exclusively industrial areas are limited to 70 dB (A) for both the day and night (table 2) (22).

Table 1. EPA guidelines for environmental noise as defined by land use type and time of day.

Land use type	Maximum noise level guidelines dB (A)	
Time period	**07:00 – 22:00**	**22:00 – 07:00**
Rural residential	47	40
Urban residential	52	45
Urban residential with light commerce or institutional	55	45
Urban residential with light manufacturing, public entertainment or licensed premises	58	50
Commercial	65	60
Industrial	70	70

Table 2. Acceptable levels of environmental noise as defined by Italian Legislation for times of day and land use type.

Land use type	**Maximum noise level guidelines dB (A)**	
Time period	**06:00 -22:00**	**22:00 – 06:00**
Protected areas	50	40
Residential areas	55	45
Mixed areas	60	50
Areas of intense activity	65	55
Predominantly industrial areas	70	60
Exclusively industrial areas	70	70

3.4 *Data Analysis*

Data analysis is typically conducted using descriptive statistical methods. The simplest of these is where the maximum (L_{Amax}) and minimum (L_{Amin}) noise levels are the highest and lowest levels observed respectively. Other common statistical descriptors include L_{A1}, L_{A5}, and L_{A90} and are used to describe the noise in a specified percentile of the sample period. L_{A1} and L_{A5} measure the highest levels of sound and are commonly used to assess traffic noises while L_{A90} is used to examine background environmental noise. As statistical descriptors can be cumbersome, the equivalent sound level (L_{eq}) is used to describe the average sound level during a stated period of time and is used as a common substitute. Composite whole–day ratings are also used to describe environmental noise and two ratings are commonly employed. Day-Night Level (L_{dn}) uses two L_{eq} values - one for day and one for night while Day-Evening-Night (L_{Rden}) uses three L_{eq} values and produces a more accurate reflection of ambient environmental noise. All of these statistical descriptors are in common use and calculation methods are described in ISO 1996-1 (25;32;35). Results are usually presented as thematic maps to display spatial variation while line graphs are used for temporal variation (23). Tables, box-and-whisker diagrams and histograms are frequently used to compare between different testing locations (25).

4. METHODS

Two neighbourhoods on the Halifax peninsula area were identified as representative of residential and mixed use environments in urban Halifax. These areas were selected from regions delineated by the Federal Government as dissemination areas, part of the national census program; dissemination areas are the smallest units used by the census program. Several of these areas make up each census tract, resulting in tracts with similar population sizes, regardless of the physical area defined by the boundaries.

The criteria used for selecting study areas were the structure of the local built environment, the population density, the geographic region, the surrounding area, and the local land-use using data from the 2001 Canadian census and DMTI Spatial(36). All geographic information data (GIS) used, including census information, city road maps and land-use are available from the Maps & Geospatial Information Collection (MAGIC) administered by the Dalhousie GIS Centre.

4.1 *Study areas*

The chosen dissemination areas identified for the study are located in the south end of Halifax (figure 1). Area one, the representative residential area, is bound by Robie Street in the east, Bellevue and Waterloo Streets to the west, and South and Roxton Streets in the north and south respectively, giving it a north - south oriented rectangular shape. This area is predominantly composed of single-family dwellings, two to three stories in height, and has a total population of 653 permanent residents. Buildings in this area are free standing and constructed wood, stone and brick. The total area of the Area one is 0.16 Km^2 and it has a population density of 3967.2 per km^2. There are a total of seven streets inside the boundaries of the region and a length of 3506 m for all roads contained in the sample region.

Area two, the mixed use area, has a larger area of 0.30 km^2, but a smaller population of 566, resulting in a population density of 1836.5 per Km^2. This area is bound by Hollis and Barrington Streets in the east, South Park, Brenton and Queen Streets in the west, Sackville Street to the north, and Spring Garden, Clyde, Morris, and Bishop Streets in the south. Area two does not have a regular shape but is generally oriented east-west. This area contains commercial, institutional, and residential zones, with multi-story buildings primarily build out of concrete. There are 16 internal streets with a total road length of 6271 m.

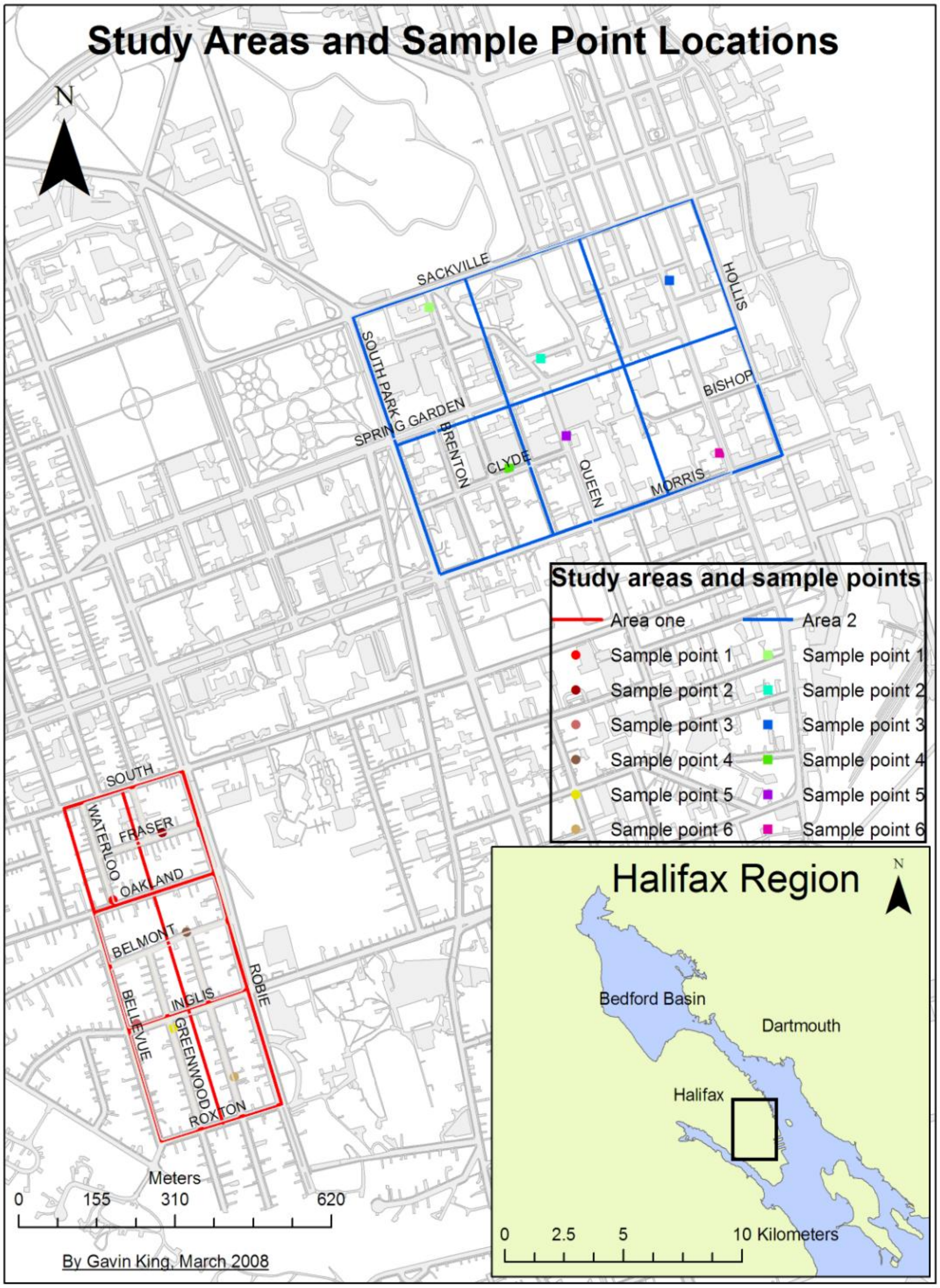

Figure 1. Map of study areas with Area 1 in red and Area 2 in blue, sample sites are also identified.

4.2 *Instrumentation*

Instrumentation used in this study includes a Centre 322 Logging Sound Level Meter (SLM) and a Marantz PMD-660 Solid State Digital Recorder (figure 2). The Centre SLM is an ANSI S1.4 Type 2 instrument with a 0.5" electrets condenser microphone, and with a frequency range of 31.5 Hz to 8 KHz, and a measuring level range of 30 to 130 dB. This instrument can weight frequencies to either the A or C scale, and adjust the time weighting for either fast (125 ms) or slow (1 sec) response. Under reference conditions, the SLM has an accuracy of +/- 1.5 dB at 94 dB, 1 KHz and can be manually calibrated. Logging capabilities of the unit include an onboard memory of 32 000 data points and it can be connected to a Windows-based computer

Figure 2. Center 322 SLM (white) and Marantz 660 recorder (black) with microphone, wrist watch for scale.

via a RS232 port for either direct logging or to download stored information. The accompanying software allows the collected data to be displayed in either graphical or tabular format(37).

The Marantz PMD-660 Solid State Digital Recorder has a sampling frequency of 44.1, 48 KHz with a frequency response of 16,000 Hz. The recorder is connected to an external microphone and it can record 4 hours of data at the stated frequency, which can be downloaded to a computer for analysis (38).

4.3 *Sampling periods*

The study was conducted using a 45-minute sampling period for all samples. Each sample location was characterized by three hours of data distributed over each of the four time divisions identified in table one. The hour in which the sample was conducted was randomly assigned to different sample points but in a manner that insured the full six hour period was sampled. Each sample was started at the top of the hour. Sample point locations are based on the sample grid system identified in ISO standard 1996-2 as being the most effective manner of assessing environmental noise with one randomly located sample point in each grid square.

4.4 *Sample Points*

The location of the random sample points was determined by GIS manipulation of the Halifax city roads map file in ArcGIS. A four meter buffer was created inside the curb, away from the roads, inside the study area to create the sample area. To do this a new feature layer is created in ArcCatalog, and the curbs of all streets inside the study areas are traced by using the editor tool. A four meter wide buffer is then generated by ArcGIS on the internal side of the curb of the study area using the buffer tool. The study areas were divided into six sample squares defined by the size of the sample area, the roads buffer polygon is extracted from inside each grid square. A random point is then generated by Hawth's Analysis Tools for ArcGIS inside the buffered area. This produces a grid sampling plan with a randomly identified point in each grid square in the four meter buffered region from each road.

Measurements collected in this study were taken at a height of 1.5 m, at a distance of 0.5 m from the curb, with the SLM oriented perpendicular to the nearest road. The SLM and sound recorder were mounted on a camera tripod and a microphone stand which were locked in place. The SLM averages one second measurements while the sound recorder produced a continuous record. Measurements were not taken on days with rain, snow or high winds, because these elements can both damage equipment and decrease the accuracy of the measurements.

4.5 *Analysis*

The SLM data provides the minimum and maximum sound pressure level (SPL) averaged over one second, resulting in 2700 data points for each sample, and 10800 data points for each grid sample area in a 24-hour period. The sound recorder provided continuous recording which was used to identify peak noise events. Basic noise descriptors, including maximum and minimum, mean, and various percentile sound levels which are used to describe the level of sound equalled or exceeded during the identified percentage of a time period. Also, equivalent continuous sound pressure levels (L_{eq}) and day – evening – night composite whole-day rating level (L_{rden}) descriptors were then produced for the sample periods, grid sample areas and study areas to identify variations in environmental noise over both space and time.

The two study areas were compared both spatially and temporally using statistical analysis of the environmental noise. Each study area was examined individually to determine spatial variation of environmental noise during each six hour sample period, as well as during the full 24-hour period. Comparative analysis between the individual sample sites was conducted using Kruskal – Wallis tests while analysis between the two study areas was conducted using the Mann-Whitney two sample rank test and Leven's test.

The Kruskal–Wallis test is used when there is one nominal variable and one measurement variable which does not meet the normality assumption of ANOVA. A one-way ANOVA may yield inaccurate estimates of the P-value when the data are very far from normally distributed. The Kruskal–Wallis test does not make assumptions about normality; it is performed on ranked data, so the measurement observations are converted to their ranks in the overall data set. The Mann-Whitney U test is a non-parametric test for assessing whether two samples of observations come from the same distribution. The null hypothesis is that the two samples are drawn from a single population, and therefore that their probability distributions are equal (39). The Levene's test tests the null hypothesis that the population variances are equal. If the resulting value is significant at the identified level the variance between the two populations is unlikely to have occurred based on random sampling (40).

4.6 *Health Comparisons*

By using the available acceptable levels of environmental noise from the EPA and Italian legislation for the appropriate land use types, a base was established for comparison purposes. The data was then recalculated to conform to the standardized time periods. The two sample areas were compared to the established guidelines using both un-weighted and weighted L_{Aeq} values, to include disturbance impact of time of day, to examine the acceptability levels of environmental noise and to assess the health risks to the local population.

5. DATA PRESENTATION AND ANALYSIS

Data recorded during this study includes 36 hours of both sound recording and SLM data points. Each of the areas are characterized by 18 hours of data with each site having three hours, with four samples of 45 minutes providing 2700 data points for each 45 minute sample. For each sample a L_{Aeq} has been calculated using formula (1) producing the A scale weighted equivalent continuous sound pressure level as described in the ISO 1996-1 standards (35).

$$L_{Aeq} = \frac{10\left(\log\frac{1}{T}\right)\int P_a^{\,2}(t)}{p_o^{\,2}(dt)} \qquad (1)$$

Where:

$P_A^{\,2}$ is the A-weighted instantaneous sound pressure at the running time t;

p_o is the standard reference sound 20 μPa;

The L_{Aeq} values were then adjusted according to Annex A of the ISO 1996-1 standards to reflect the time period in which the sample was taken. Annex A allows an adjustment of +5 dB for the evening hours and +10 for the night hours to reflect the disturbance of the sounds using formula (2) to produce and adjusted L_{Aeq}.

$$L_{\mathrm{Re}qj,Tn} = L_{Aeqj,Tn} + K_j \qquad (2)$$

Where:

K_j Is the adjustment for the specified sample and time period;

$L_{Aeqj,Tn}$ Is the actual L_{Aeq} at the specified time period;

Using the adjusted L_{Aeq} values the composite whole-day rating level was then calculated to develop a day-evening-night rating level using equation (3).

$$L_{Rden} = 10\log\left[\frac{d}{24}x10^{\frac{LRD}{10}} + \frac{e}{24}x10^{\frac{L\,\mathrm{Re}}{10}} + \frac{(24-d-e)}{24}x10^{\frac{LRn}{10}}\right]db \qquad (3)$$

Where:

d is the number of daytime hours;

n is the number of night-time hours;

e is the number of evening hours;

LRd is the rating level for daytime hours including adjustments;

LRe is the rating level for evening hours including adjustments;

LRn is the rating level for night-time hours including adjustments;

5.1 *Area one*

Area one sample points show variation between both individual sites and sample periods. Maximum values for the individual sites ranged from 63.7 dB (A) to 93.3 dB (A) with most site values in the 70's. L_{A90} values for the sample sites range from a low of 38.2 dB (A) to a high of 50 dB (A) and represent the background noise levels of the area. Non-adjusted L_{Aeq} values range from 42.7 dB (A) to 69.1 dB (A) with the difference between the maximum and minimum L_{Aeq} values for all sites between 9.6 and 13.4 (table 3). When the data points for area one are grouped into the four sample time periods and averaged the values for the maximum SPL levels are between 71.3 dB (A) and 77.4 dB (A). L_{A90} values for the four time periods range

Table 3. Summary table of various statistical values for Area 1.

Area 1						**Percentiles**							
Sample Site	**Period**	**Start Time**	**Maximum**	**Min**	**Mean**	**L_{A1}**	**L_{A5}**	**L_{A10}**	**L_{A90}**	**L_{A95}**	**L_{A99}**	**L_{Aeq}**	**Adjusted L_{Aeq}**
1	**1**	**7:00**	73	40.1	44.2	60	51.1	46.9	41.8	41.4	40.6	48.5	48.5
	2	**16:00**	73.3	41.4	47.7	65.1	59.1	56.3	42.8	42.4	41.8	53.2	53.2
	3	**18:00**	66.6	25.8	43.9	61.8	55	51.5	39.5	38.9	38.4	49.2	54.2
	4	**3:00**	66.3	41.7	43.9	51.6	45.5	44.9	42.8	42.6	42	45	55
									Maximum L_{Aeq}			**53.2**	**55**
									Minimum L_{Aeq}			**45**	**48.5**
									Difference			**8.2**	**6.5**
2	**1**	**8:00**	72.9	43.7	51.3	67.4	60.6	57	46.3	45.6	44	55.4	55.4
	2	**12:00**	75.4	40.9	48	63.7	56.2	53.3	43.3	42.9	43.3	53	53
	3	**22:00**	65.2	21	44.2	55.9	51.5	49.1	41.5	41.2	40.8	46.6	51.6
	4	**1:00**	66.3	38.8	40.3	49.2	42.2	40.9	39.4	39.3	39.2	42	52
									Maximum L_{Aeq}			**55.4**	**55.4**
									Minimum L_{Aeq}			**42**	**51.6**
									Difference			**13.4**	**3.8**
3	**1**	**9:00**	90	42.3	61.4	80.3	73.4	71.8	48	46.1	43.9	69.1	69.1
	2	**14:00**	86.6	40	57.7	76.3	72.5	70.3	45.7	43.2	41.1	66.3	66.3
	3	**23:00**	81.4	37	43.1	72.1	62.3	54.3	38.2	37.9	37.5	58.6	63.6
	4	**5:00**	93.3	20	48	77.6	67.7	59.1	43.3	43.1	42.8	66.8	76.8
									Maximum L_{Aeq}			**69.1**	**76.8**
									Minimum L_{Aeq}			**58.6**	**63.6**
									Difference			**10.5**	**13.2**

Table 3 (Continued). Continuation of table three showing statistical values for Area 1.

Area 1						Percentiles							
Sample Site	**Period**	**Start Time**	**Maximum**	**Min**	**Mean**	L_{A1}	L_{A5}	L_{A10}	L_{A90}	L_{A95}	L_{A99}	L_{Aeq}	**Adjusted** L_{Aeq}
4	**1**	**10:00**	79.8	47	58.1	73.8	69.5	67.1	50.3	49.4	47.7	63.1	63.1
	2	**15:00**	77.5	23	49	66.7	59	56.7	43	42.3	41.5	54.8	54.8
	3	**21:00**	78.9	43.9	53.8	71.3	66.6	63.7	46.8	46.1	44.8	60	65
	4	**24:00**	77.4	39.9	45.8	63.5	58.1	55	41.3	41	40.6	52.9	62.9
									Maximum L_{Aeq}			**63.1**	**65**
									Minimum L_{Aeq}			**52.9**	**54.8**
									Difference			**10.2**	**8.3**
5	**1**	**11:00**	72.7	41.6	50.8	66.6	60.5	58.8	43.9	43.2	42.3	55.4	55.4
	2	**13:00**	77.5	23	49	66.7	59	56.7	43	42.3	41.5	54.8	54.8
	3	**19:00**	73.9	37.8	48.4	65	59.8	57.1	40.5	39.8	38.8	54.2	59.2
	4	**4:00**	63.7	42.2	44.4	53.4	46.9	45.7	43	42.8	42.4	45.2	55.2
									Maximum L_{Aeq}			**54.8**	**59.2**
									Minimum L_{Aeq}			**45.2**	**54.8**
									Difference			**9.6**	**4.4**
6	**1**	**6:00**	67.9	40.5	43.1	50	45.6	44.3	41.9	41.7	41.3	44.7	44.7
	2	**17:00**	73.8	42.6	49.8	66.5	59.6	56.4	45.6	45	43.9	54.6	54.6
	3	**20:00**	73.4	41.2	45.5	61.7	51.6	48.9	43	42.6	42	50.3	55.3
	4	**2:00**	60.6	38.3	41.7	51.5	44.6	42.8	40.2	39.7	38.8	42.7	52.7
									Maximum L_{Aeq}			**54.6**	**55.3**
									Minimum L_{Aeq}			**42.7**	**44.7**
									Difference			**11.9**	**10.6**

from a low of 41.6 dB (A) to a high of 45.4 dB (A) while non-adjusted L_{Aeq} values range from a low of 49.1 dB (A) to a high of 56 dB (A) (table 4).

Area one shows a highly variable amount of sound both spatially and temporally. A few sample sites have statistically greater levels of environmental noise as well as significant peaks in the maximum SPL level. Sites three and four show higher than average L_{A1} (figure 3) and L_{A5} SPL levels, indicating high levels of road traffic near the sample points. The L_{A90} levels representing the background levels of environmental noise are more consistent with other sample points in Area one (figure 4).

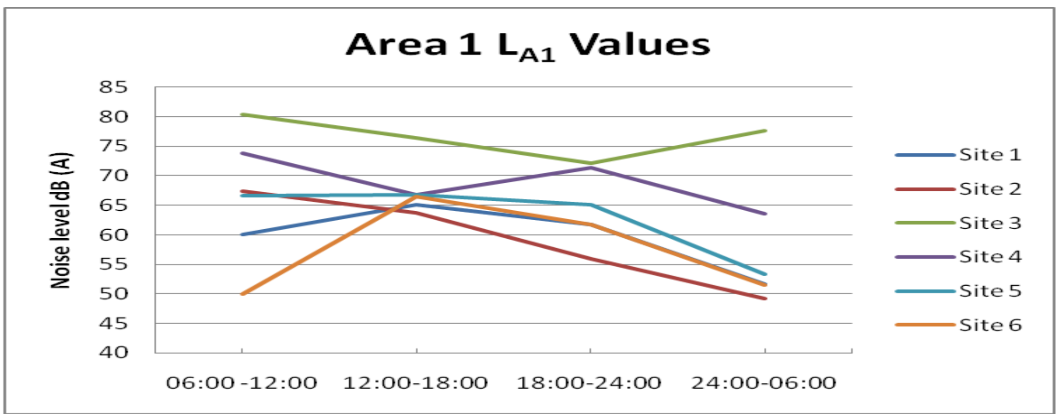

Figure 3. Area 1 L_{A1} values for the four sample time periods, LA1 is a measure of environmental noise from traffic

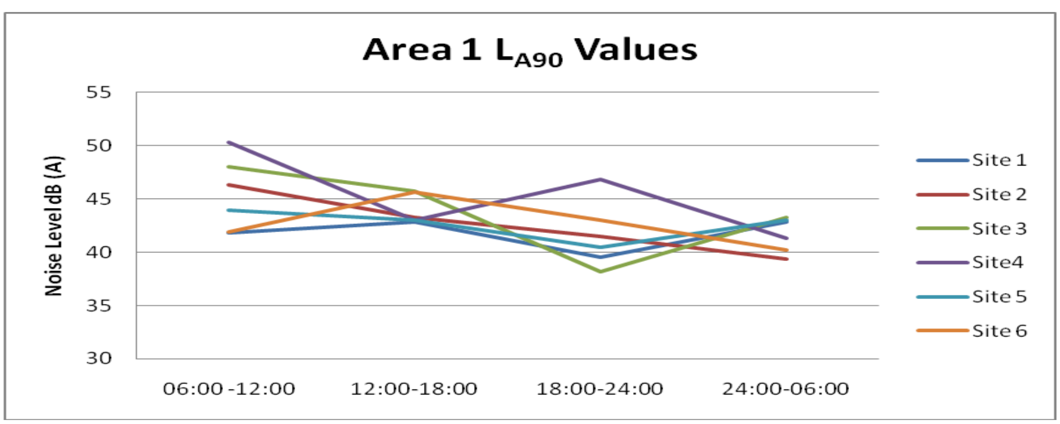

Figure 4. Area 1 L_{A90} values which represent the background environmental noise levels.

Table 4. Statistical values for Area 1 distributed by sample time period.

Area 1 Divided by Period								
Morning				**Percentiles**				
Site	**Time**	**Maximum**	**Mean**	**L_{A1}**	**L_{A10}**	**L_{A90}**	**L_{Aeq}**	**Adjusted L_{Aeq}**
6	**6:00**	67.3	43.1	50	44.3	41.9	44.7	44.7
1	**7:00**	73	44.2	60	46.9	41.8	48.5	48.5
2	**8:00**	72.9	51.3	67.4	57	46.3	55.4	55.4
3	**9:00**	90	61.4	80.3	71.8	48	69.1	69.1
4	**10:00**	79.8	58.1	73.8	67.1	50.3	63.1	63.1
5	**11:00**	72.7	50.8	66.6	58.8	43.9	55.4	55.4
	Average	**76.0**	**51.5**	**66.4**	**57.7**	**45.4**	**56.0**	**56.0**
Afternoon								
2	**12:00**	75.4	48	63.7	53.3	43.3	53	53
5	**13:00**	77.5	49	66.7	56.7	43	54.8	54.8
3	**14:00**	86.6	57.7	76.3	70.3	45.7	66.3	66.3
4	**15:00**	77.5	49	66.7	56.7	43	54.8	54.8
1	**16:00**	73.3	47.7	65.1	56.3	42.8	53.2	53.2
6	**17:00**	73.8	49.8	66.5	56.4	45.6	54.6	54.6
	Average	**77.4**	**50.2**	**67.5**	**58.3**	**43.9**	**56.1**	**56.1**
Evening								
1	**18:00**	66.6	43.9	61.8	51.5	39.5	49.2	54.2
5	**19:00**	73.9	48.4	65	57.1	40.5	54.2	59.2
6	**20:00**	73.4	45.5	61.7	48.9	43	50.3	55.3
4	**21:00**	78.9	53.8	71.3	63.7	46.8	60	65
2	**22:00**	65.2	44.2	55.9	49.1	41.5	46.6	51.6
3	**23:00**	81.4	43.1	72.1	54.3	38.2	58.6	63.6
	Average	**73.2**	**46.5**	**64.6**	**54.1**	**41.6**	**53.2**	**58.2**
Night								
4	**24:00**	77.4	45.8	63.5	55	41.3	52.9	62.9
2	**1:00**	66.3	40.3	49.2	40.9	39.4	42	52
6	**2:00**	60.6	41.7	51.5	42.8	40.2	42.7	52.7
1	**3:00**	66.3	43.9	51.6	44.9	42.8	45	55
5	**4:00**	63.7	44.4	53.4	45.7	43	45.2	55.2
3	**5:00**	93.3	48	77.6	59.1	43.3	66.8	76.8
	Average	71.3	44.0	57.8	48.1	41.7	49.1	59.1
		Maximum	**mean**	**1%**	**90%**	**Laeq**	**Adjusted LAeq**	
	morning	76	51.5	66.4	45.4	56	56.0	
	afternoon	77.4	50.2	67.5	43.9	56.1	56.1	
	evening	73.2	46.5	64.6	41.6	53.2	58.2	
	night	71.3	44	57.8	41.7	49.1	59.1	

When L_{Aeq} values for the full day are plotted, there are anomalous L_{Aeq} peaks located at 05:00, 09:00, 14:00, 21:00, 23:00 and 00:00 with a smaller peak at 19:00 (figure 5). Data for 05:00, 09:00, 14:00, and 23:00 is from site three while 21:00 and 24:00 is from site four and the smaller peak at 19:00 is data from site five demonstrating the impact of higher volumes of traffic noise on environmental noise levels. Non-adjusted L_{Aeq} values reflect the same pattern as the maximum and road traffic values with sites three and four pulling the study area average upwards. Using equation (3) the composite whole day rating for Area one is 63.8 dB (A)

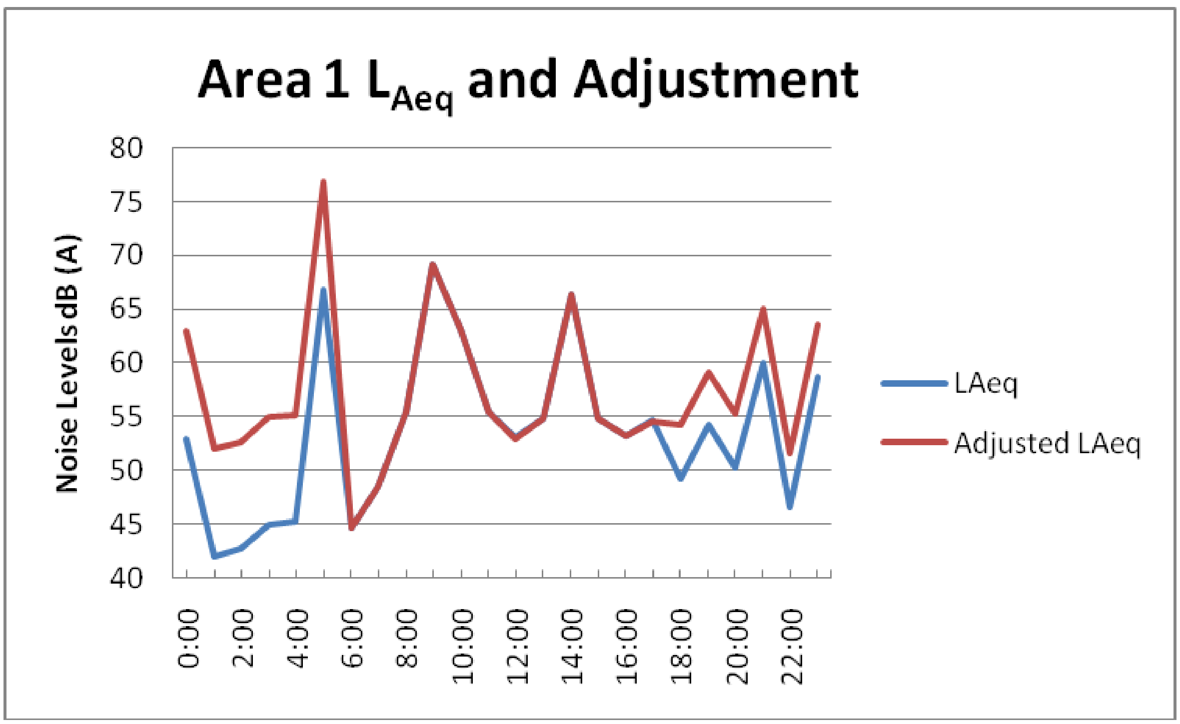

Figure 5. Area 1 full 24-hour L_{Aeq} values with adjustment.

A histogram plot of all data points recorded in Area one demonstrates a skewed right normal distribution with a mean dB (A) of 48.05 and a standard deviation of 7.06 demonstrating a minimum level of environmental noise and the significance of traffic noise on the data point distribution (Figure 6).

Individual sample sites vary greatly in data point distribution both between sites and between sample periods as the same site. Boxplots and interval plots (CI, 95%) reveal differences in the structure of specific site data between sites with more or less environmental noise. Site 6, exhibits the lowest level of environmental noise in the area. This site also presents a low IRQ box with significant numbers of high outlier values throughout the day which correspond to elevated noise events that could cause disturbance. In night and early morning samples low outliers also occur which are moments of very low amounts of environmental noise. Standard deviation from the mean averaged for all sample periods in site

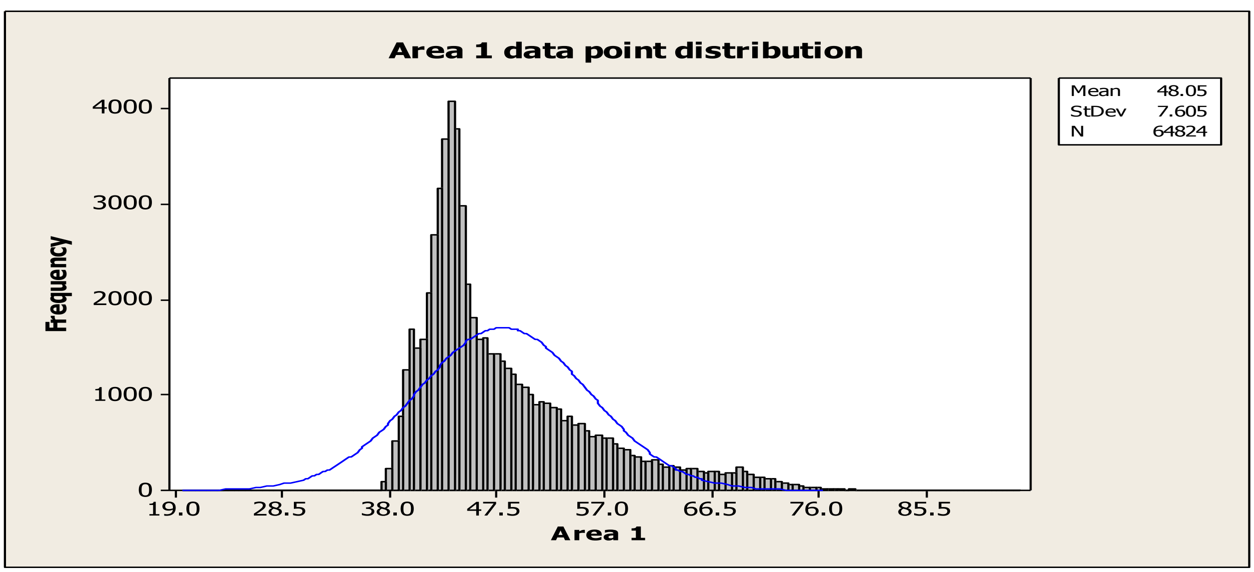

Figure 6. Histogram plot of all Area one data points illustrating a skewed right normal data distribution and offset fits line.

6 is 3.015 (figure 8).

Sample site 3 which had the highest levels of environmental noise in Area 1 demonstrates a different data distribution pattern. Site 3 exhibits higher IRQ boxes and fewer outlier points, all of which are in the evening and night sample time periods. During the day there is a steady background level of traffic absent from sites more distant from high traffic roads and the traffic events blend into the background noise (figure 9). Average standard deviation from the mean for site 3 is 8.546.

To examine if the individual sample sites in Area one have statistically different levels of environmental noise a Kruskal - Wallis Test was conducted (figure 7). This test presents sufficient evidence to reject the null hypothesis that all median values are equal in favour of the alternative hypothesis which states at least one is not equal in terms of environmental noise level at a significance level of 95%.

Kruskal-Wallis Test – area 1

Test Statistics[a,b]

	adjlaeq
Chi-Square	16.232
df	5
Asymp. Sig.	.006

a. Kruskal Wallis Test

b. Grouping Variable: Sample Site

Figure 7. Kruskal-Wallis test for area 1 sample sites exhibiting sufficient evidence to reject the null hypotheses.

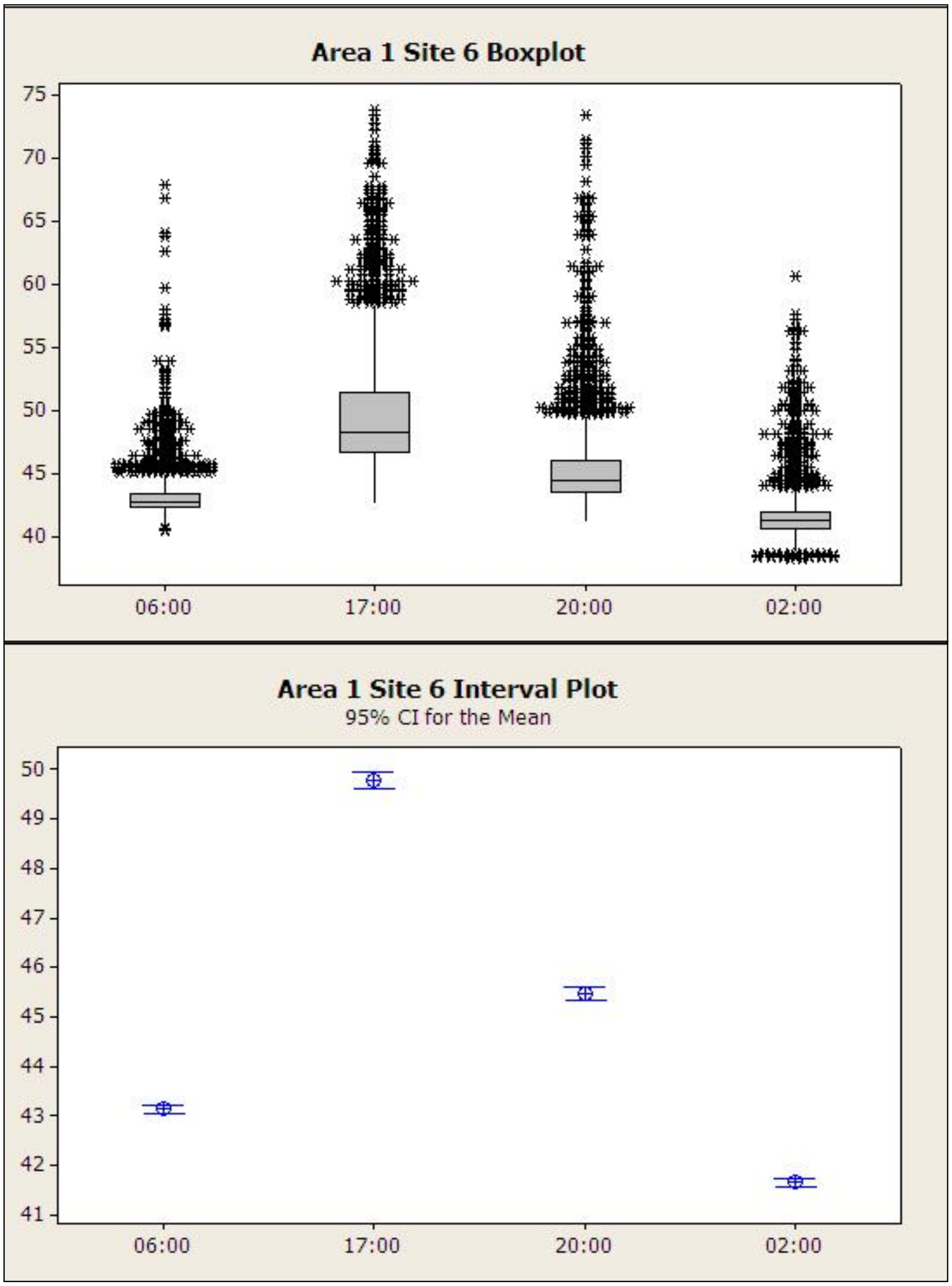

Figure 8. Boxplot and 95% mean confidence interval for site 6, Area 1. Sample start time on the horizontal axis with SPL in dB (A) on the vertical axis.

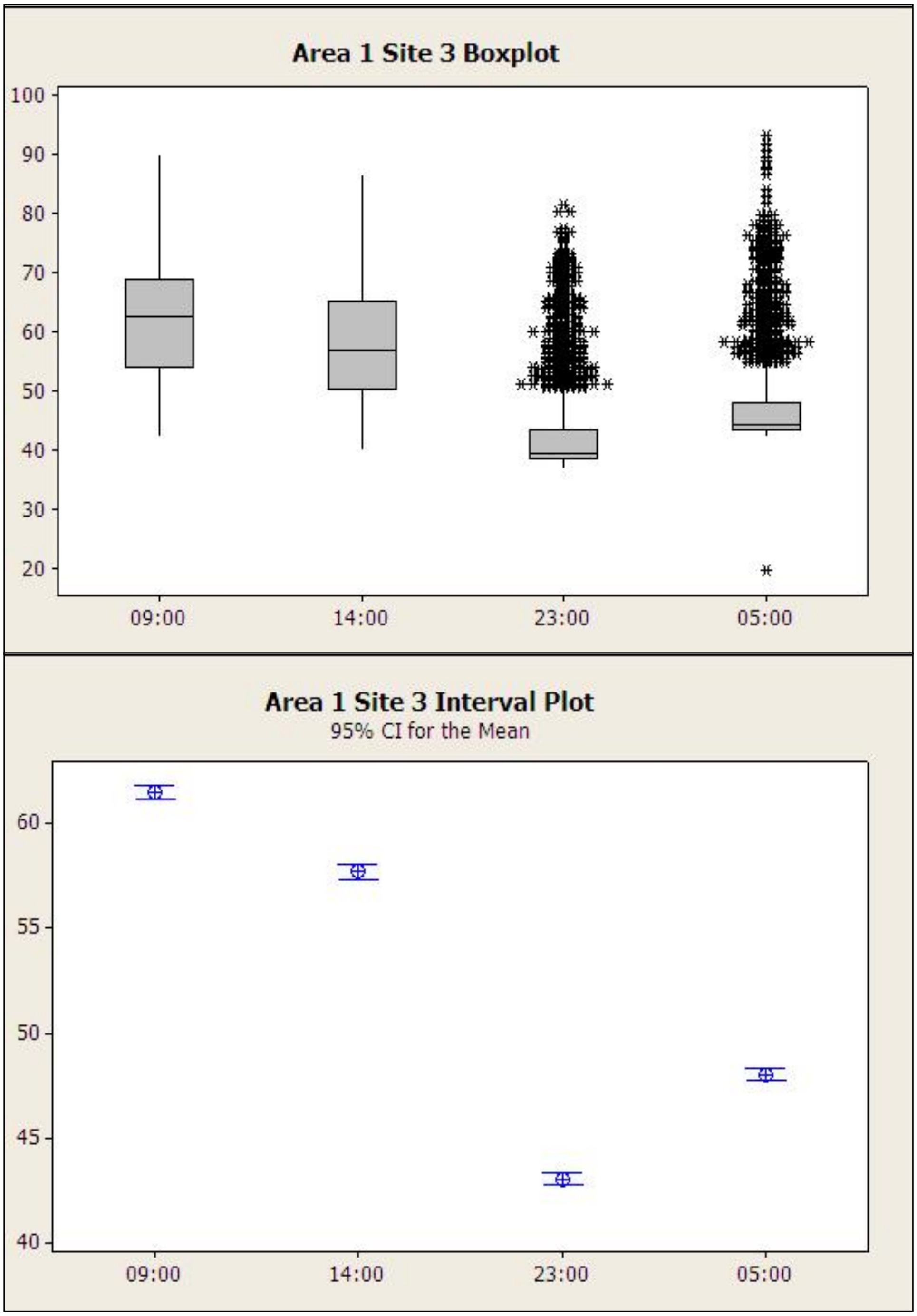

Figure 9. Boxplot and 95% mean confidence interval for site 6, Area 1. Sample start time on the horizontal axis with SPL in dB (A) on the vertical axis.

5.2 *Area two*

Sample points in Area two exhibit less variation between recorded values for individual sites and the sample periods than Area one. Peak SPL levels range from 90.3 dB (A) to 69.7 dB (A) while L_{A90} values range from a high of 59.3 dB (A) to a low of 44 dB (A). Area non adjusted L_{Aeq} values range from 71.1 dB (A) to 49.6 db (A) while the difference between the maximum and minimum L_{Aeq} levels range from 15.4 dB (A) and 5.1 dB (A) (table 5). Time period data for Area two presents average maximum SPL levels between 84.9 dB (A) and 77.2 dB (A) while L_{A90} averaged values range from 54.6 dB (A) and 47.1 dB (A). Non-adjusted L_{Aeq} for Area two time periods range from 64.1 dB (A) to 56.1 dB (A) (table 6).

Area two, the mixed use area, demonstrates a more consistent level of environmental noise across all the sample sites. Over the four time periods maximum SPL as well as L_{A1} (figure 10) and L_{A5} are similar for all sites demonstrating a consistent level of vehicular noise throughout the area over the full day. L_{A90} is highest in the afternoon at 54.6 dB (A), similar to the morning reading of 53.1 dB (A) and decreases through the evening to 47.1 dB (A) at night (figure 11).

Table 5. Summary table of various statistical values for Area 2

Area 2						Percentiles							
Sample Site	**Period**	**Start Time**	**Maximum**	**Min**	**Mean**	L_{A1}	L_{A5}	L_{A10}	L_{A90}	L_{A95}	L_{A99}	L_{Aeq}	**Adjusted** L_{Aeq}
1	**1**	9:00	87	52.3	63.1	79.1	74.1	70.5	56.4	55.2	53.4	68.2	68.2
	2	12:00	88.3	55.4	65.1	75.9	71.6	70.1	59.3	58.4	57.3	58.1	58.1
	3	20:00	77.3	49.1	56	69.1	64.5	61.6	51.4	50.7	49.8	59	64
	4	2:00	79.4	42.3	50	65.3	59.7	56.7	45.9	45.1	44.1	55.8	65.8
									Maximum L_{Aeq}			**68.2**	**68.2**
									Minimum L_{Aeq}			**55.8**	**58.1**
									Difference			**12.4**	**10.1**
2	**1**	8:00	89	46.7	58.3	75.1	71.8	67.4	52.2	51.1	49.2	65	65
	2	14:00	85.9	46.7	56	69.3	63.9	61.1	51.9	51.2	50.2	60.8	60.8
	3	23:00	77.8	48.9	53.4	67.3	60.5	58.3	50.2	49.8	49.4	56.7	61.7
	4	4:00	69.7	42.5	47.3	59.9	53.3	50.7	44.9	44.4	43.5	49.6	59.6
									Maximum L_{Aeq}			**65**	**65**
									Minimum L_{Aeq}			**49.6**	**59.6**
									Difference			**15.4**	**5.4**
3	**1**	10:00	86.8	54.5	60.8	77	73.4	67.8	56.2	55.7	55	66	66
	2	15:00	85.2	54.3	60.3	71.6	66.9	65.1	56.6	56.2	55.6	62.7	62.7
	3	18:00	83.3	54.1	60.4	72.5	68.4	66.6	55.9	55.6	54.9	63.5	68.3
	4	5:00	75.1	49.7	54	67.5	60.2	58	51.5	51	50.4	56.4	66.4
									Maximum L_{Aeq}			**66**	**68.3**
									Minimum L_{Aeq}			**56.4**	**62.7**
									Difference			**9.6**	**5.6**

Table 5 (continuation). Continuation of summary data table of various statistical values for Area 2

Area 2						**Percentiles**							
Sample Site	**Period**	**Start Time**	**Maximum**	**Min**	**Mean**	**L_{A1}**	**L_{A5}**	**L_{A10}**	**L_{A90}**	**L_{A95}**	**L_{A99}**	**L_{Aeq}**	**Adjusted L_{Aeq}**
4	**1**	11:00	72.7	45.4	52.6	65.9	60.8	58.1	49	48.3	46.9	55.4	55.4
	2	13:00	83.4	47.3	53.7	67.7	62	59.4	50	49.4	48.4	58.5	58.5
	3	22:00	75.1	28.6	50.4	66	58.6	55.3	47.2	46.8	46.2	54.1	59.1
	4	24:00	71.9	45.7	49.7	62.9	56.2	53.4	47.3	47	46.4	52.4	62.4
									Maximum L_{Aeq}			**58.5**	**62.4**
									Minimum L_{Aeq}			**52.4**	**55.4**
									Difference			**6.1**	**7**
5	**1**	6:00	77.3	47.4	54	70.1	65.4	62.2	49	48.6	48.1	58.9	58.9
	2	16:00	86	23.7	60.9	72.1	69.1	67.1	55	53.7	51.8	64	64
	3	19:00	77.6	48.5	57.7	72.3	68.4	66.4	51.7	50.9	49.9	62.1	67.1
	4	1:00	85.7	46.2	53.8	73.5	65.9	61.4	49.1	48.7	48.1	61.3	71.3
									Maximum L_{Aeq}			**64**	**71.3**
									Minimum L_{Aeq}			**58.9**	**58.9**
									Difference			**5.1**	**12.4**
6	**1**	7:00	90.3	49.8	65.6	81.3	76.5	74.3	56	54.2	52	71.1	71.1
	2	17:00	80.4	49.6	63.1	75.7	71.9	70.2	54.9	53.6	51	66.7	66.7
	3	21:00	83.7	46.7	60.1	74.3	70.6	68.6	51.8	50.5	48.5	64.8	69.4
	4	3:00	81.4	23.6	51.7	75.6	68.6	63.6	44	43.6	43	62.2	72.2
									Maximum L_{Aeq}			**71.1**	**72.2**
									Minimum L_{Aeq}			**62.2**	**66.7**
									Difference			**8.9**	**5.5**

Table 6. Area 2 selected statistical values divided by sample period.

Area 2 Divided by Period								
Morning								
Site	**Time**	**Maximum**	**Mean**	**L_{A1}**	**L_{A10}**	**L_{A90}**	**L_{Aeq}**	**Adjusted L_{Aeq}**
5	**6:00**	77.3	54	70.1	62.2	49	58.9	58.9
6	**7:00**	90.3	65.6	81.3	74.3	56	71.1	71.1
2	**8:00**	89	58.3	75.1	67.4	52.2	65	65
1	**9:00**	87	63.1	79.1	70.5	56.4	68.2	68.2
3	**10:00**	86.8	60.8	77	67.8	56.2	66	66
4	**11:00**	72.7	52.6	65.9	58.1	49	55.39	55.4
	Average	**83.9**	**59.1**	**74.8**	**66.7**	**53.1**	**64.1**	**64.1**
Afternoon								
1	**12:00**	88.3	65.1	75.9	70.1	59.3	58.1	58.1
4	**13:00**	83.4	53.7	67.7	59.4	50	58.5	58.5
2	**14:00**	85.9	56	69.3	61.1	51.9	60.8	60.8
3	**15:00**	85.2	60.3	71.6	65.1	56.6	62.7	62.7
5	**16:00**	86	60.9	72.1	67.1	55	64	64
6	**17:00**	80.4	63.1	75.7	70.2	54.9	66.7	66.7
	Average	**84.9**	**59.9**	**72.1**	**65.5**	**54.6**	**61.8**	**61.8**
Evening								
3	**18:00**	83.3	60.4	72.5	66.6	55.9	63.5	68.5
5	**19:00**	77.6	57.7	72.3	66.4	51.7	62.1	67.1
1	**20:00**	77.3	56	69.1	61.6	51.4	59	64
6	**21:00**	83.7	60.1	74.3	68.6	51.8	64.8	69.4
4	**22:00**	75.1	50.4	66	55.3	47.2	54.1	59.1
2	**23:00**	77.8	53.4	67.3	58.3	50.2	56.7	61.7
	Average	**79.1**	**56.3**	**70.3**	**62.8**	**51.4**	**60.0**	**65.0**
Night								
4	**24:00**	71.9	49.7	62.9	53.4	47.3	52.4	62.4
5	**1:00**	85.7	53.8	73.5	61.4	49.1	61.3	71.3
1	**2:00**	79.4	50	65.3	56.7	45.9	55.8	65.8
6	**3:00**	81.4	51.7	75.6	63.6	44	62.2	72.2
2	**4:00**	69.7	47.3	59.9	50.7	44.9	49.6	59.6
3	**5:00**	75.1	54	67.5	58	51.5	56.4	66.4
	Average	**77.2**	**51.1**	**67.5**	**57.3**	**47.1**	**56.3**	**66.3**
		Maximum	**mean**	**L_{A1}**	**L_{Aeq}**	**L_{A90}**	**Adjusted L_{Aeq}**	
	morning	83.9	59.1	74.8	64.1	53.1	64.1	
	afternoon	84.9	59.9	72.1	61.8	54.6	61.8	
	evening	79.1	56.3	70.3	60.0	51.4	65.0	
	night	77.2	51.1	67.5	56.3	47.1	66.3	

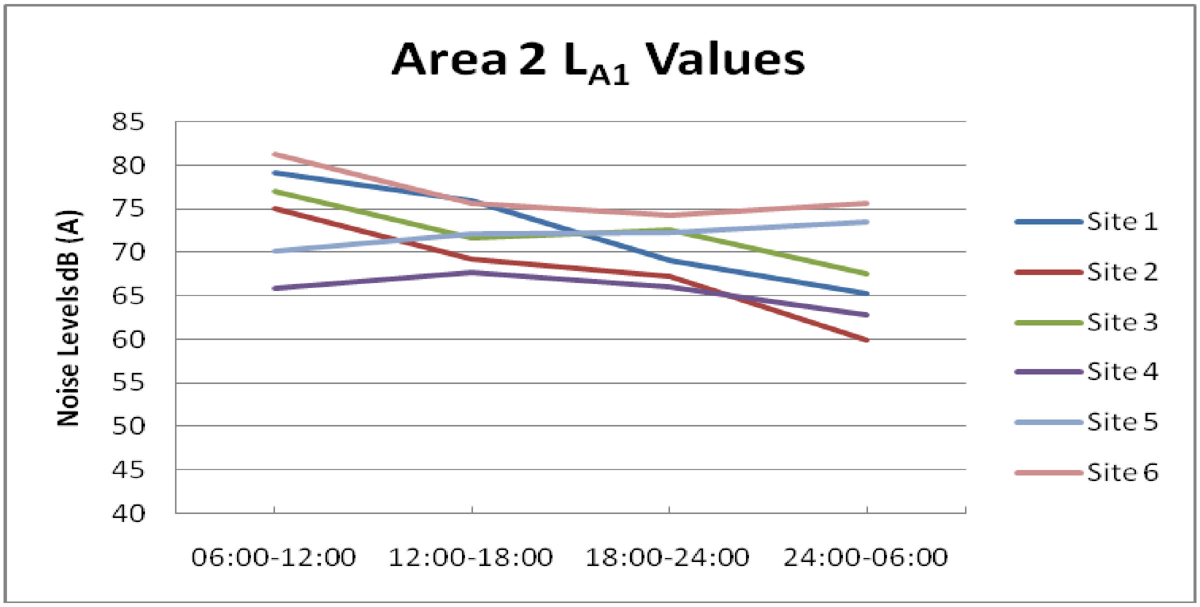

Figure 10. L_{A1} values from Area 2, representing traffic induced environmental noise.

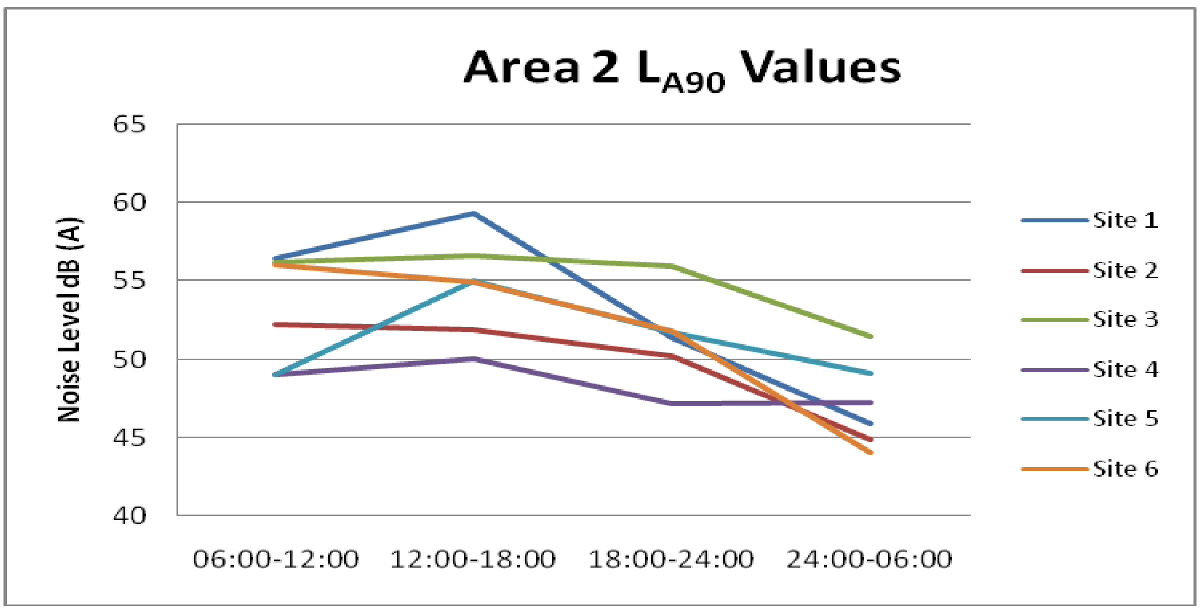

Figure 11. L_{A90} values for Area 2 by site measuring background environmental noise.

The twenty-four hour plot of L_{Aeq} for Area two demonstrates anomalous peaks at 01:00, 03:00, 07:00 and 21:00. The last three L_{Aeq} values are data from site six while the 01:00 peak is data from site 5 (figure 12). Site six is located on Barrington Street which is a high traffic street with significant bus traffic resulting in increased environmental noise.

Area two demonstrates a similar skewed right data distribution plot as Area one with a mean of 56.59 dB (A) and a standard deviation of 7.088. The data is more evenly distributed through the curve and the distribution is more symmetric (figure 13). The composite whole day rating as calculated by equation (3) gives a result of 65 dB (A).

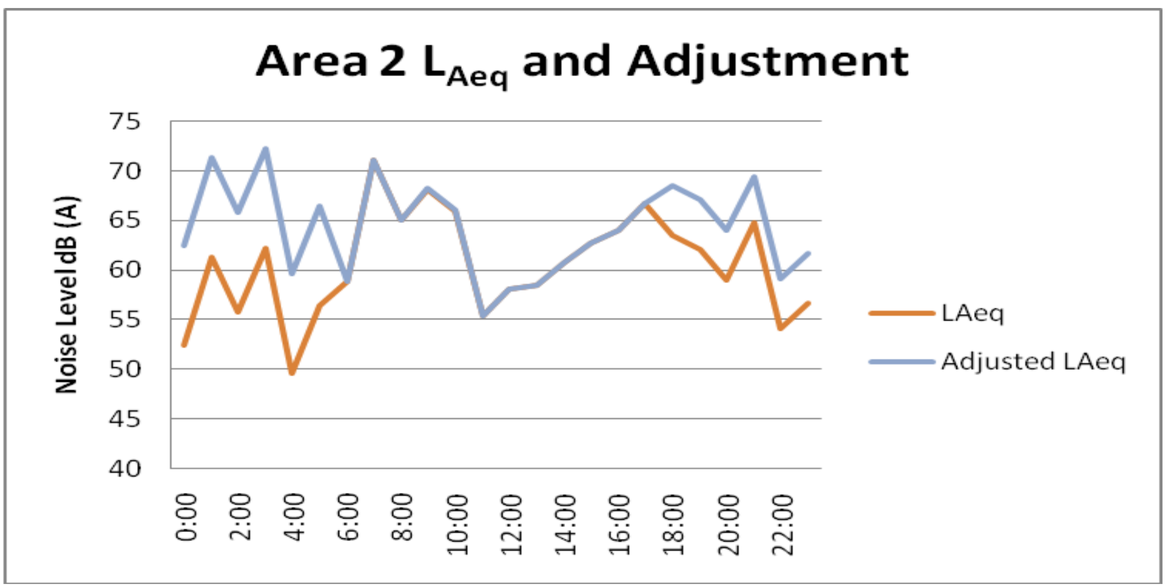

Figure 12. Area 2 L_{Aeq} and adjusted L_{Aeq} values for the full day.

Area two sample sites exhibited similar patterns of variation between sample sites and times as Area one. Sample sites near high traffic roads exhibited higher IRQ boxes and fewer outlier points (figure 14). Area two and fewer outlier points than Area one, resulting from overall higher levels of environmental noise, traffic events tend to blend into the background noise and do not cause significant increases in sound. Sample sites that have less road traffic exhibited lower IRQ boxes and more outlier points, resulting from lower ambient levels of noise (figure 15). For Area two sample sites a Kruskal – Wallis test produces a similar result as that for Area one. There is sufficient evidence to reject the null hypothesis that all sample sites have an equal median amount of environmental noise in favour of the alterative that they do not.

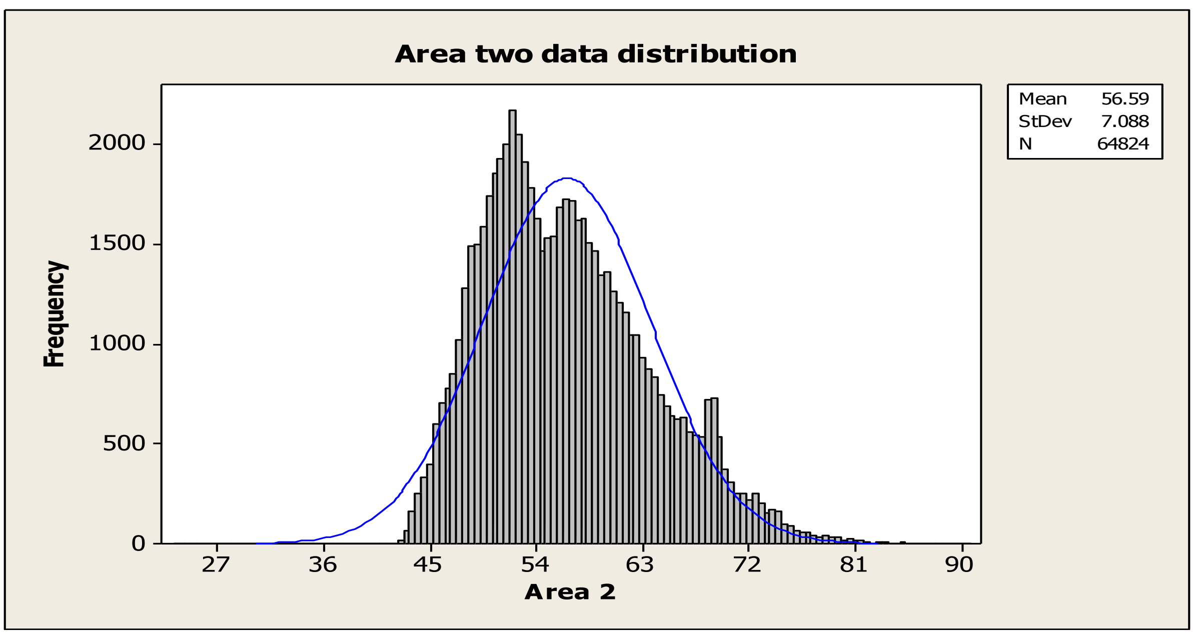

Figure 13. Distribution histogram of all data points in Area 2 and fits line.

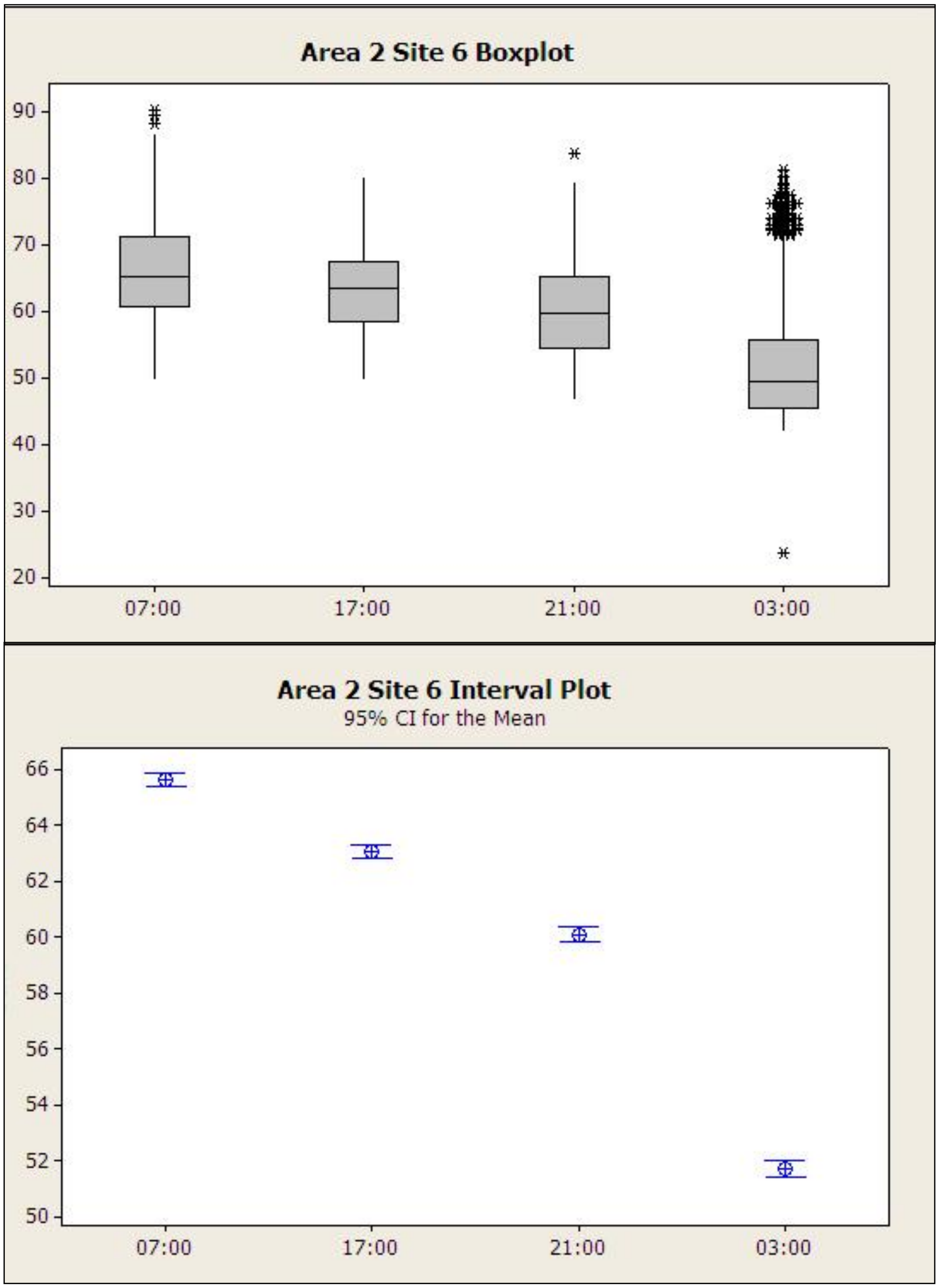

Figure 14. Boxplot and 95% confidence interval for sample site 6 Area 2. Sample start time on the horizontal axis and SPL level in dB (A) on the vertical axis.

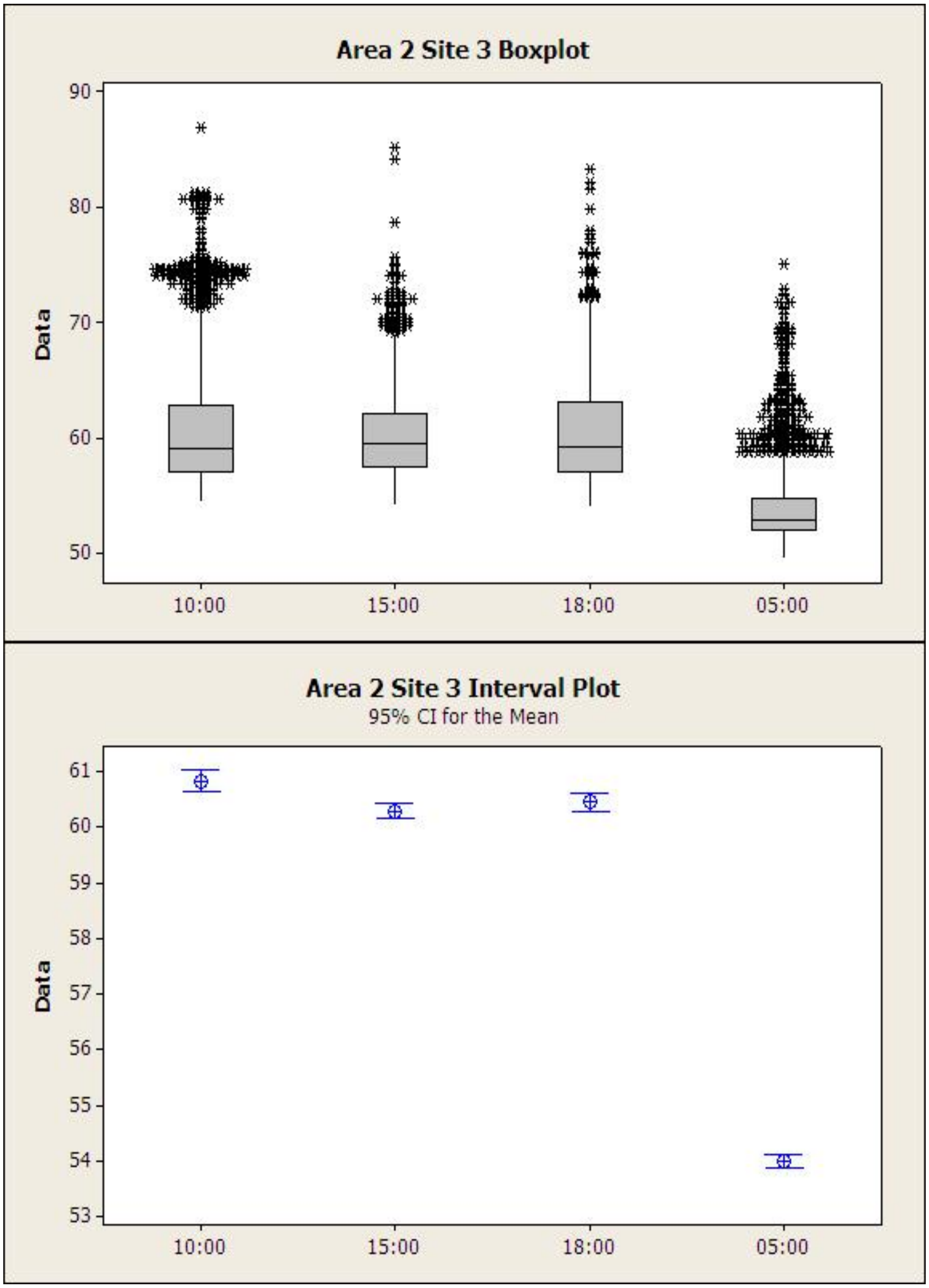

Figure 15. Boxplot and 95% confidence interval for sample site 3 Area 2. Sample start time on the horizontal axis and SPL level in dB (A) on the vertical axis.

5.3 *Analysis*

There are differences between the two sample areas, both in terms of distribution of sound and overall levels of environmental noise. Adjusted L_{Aeq} values are more variable between sample sites in Area one than sample sites in Area two (figure 16). The difference between the sites is an artefact of the variability of traffic volumes related to land use, background institutional noise and pedestrian activity. The noisier sites in Area one are those near major roads while the quieter sites are the most distant from the same roads. Area two has higher levels of environmental noise with more consistency between the sample sites. There is some variability between the sites but due to the overall greater level of vehicular traffic in the overall area the inconsistency is lower. There is significantly more institutional and

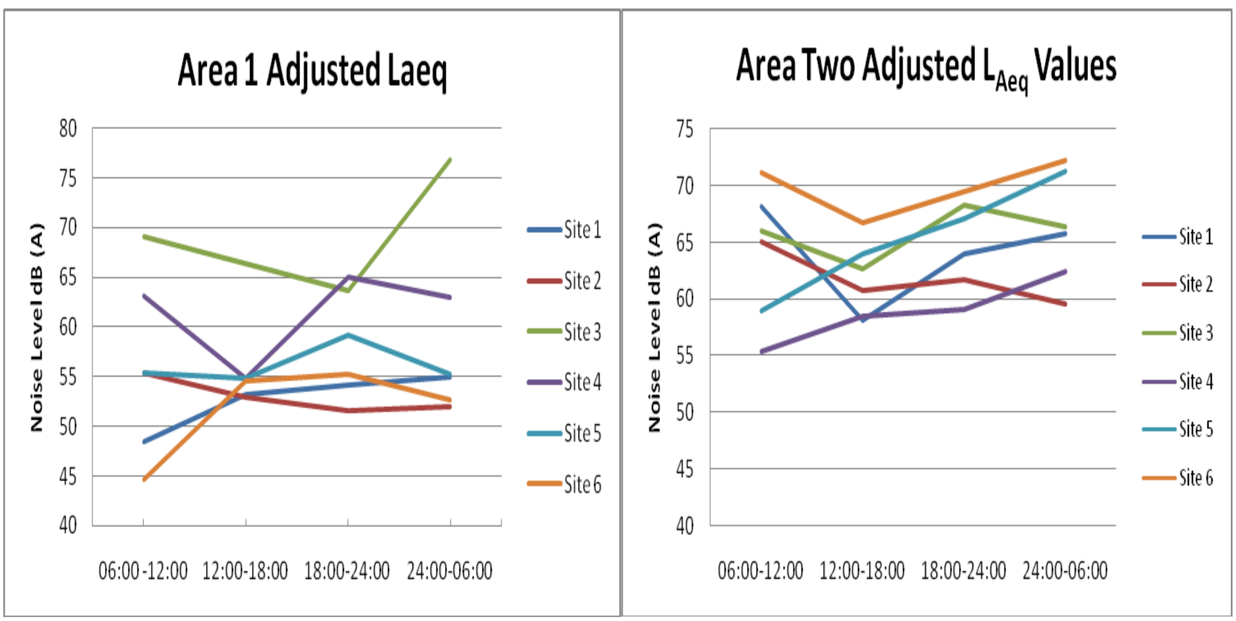

Figure 16. Area 1 & 2 adjusted L_{Aeq} values for all sites. Area 1 demonstrates much more variability between sample sites.

industrial noise in Area two as a result of the land use. This includes ventilation systems, delivery vehicles and increased levels of pedestrian activity.

The L_{A90} level of environmental noise is lower in Area one than Area two. Area two has more background noise throughout the day resulting from vehicle traffic in the area, industrial noises like ventilation fans, delivery trucks and high pedestrian traffic. Similarly the adjusted L_{Aeq} values for Area one are lower than those in Area two as a result of the land use (figure 17).

Area one is more vulnerable to the disturbance effects of noise events. A vehicle passing through Area one could cause a increase of sound of 10 to 30 dB (A) causing residence disturbance while in Area two the same vehicle may either be lost in the higher background level of sound or increase the levels of sound by a smaller amount. The composite full day rating (L_{Rden}) values for the two areas show very little difference in daily sound exposure. Area one is 63.8 dB (A) and Area two is 65 db (A).

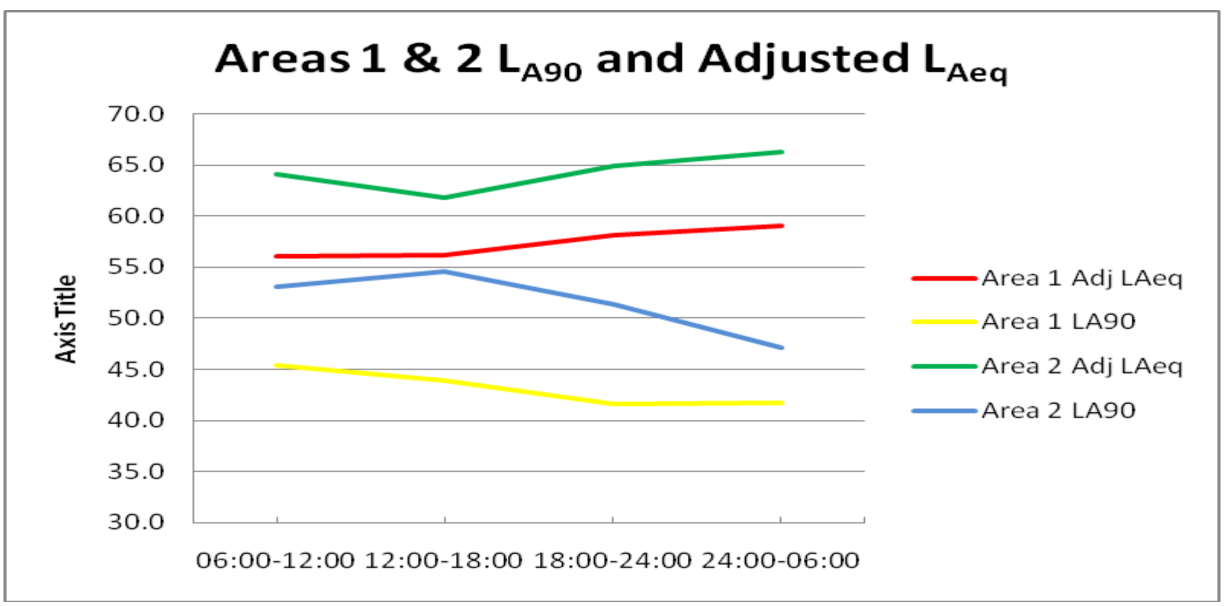

Figure 17. Areas 1 & 2 L_{A90} and Adjusted L_{Aeq} values area 2 values are approximately 10 dB (A) higher.

Using the EPA and Italian environmental noise guidelines for human health, Area one adjusted and non-adjusted L_{Aeq} values exceed both sets of guideline values by several decibels. Area two unadjusted L_{Aeq} values are considered acceptable under EPA guidelines but are unacceptable during the night for the Italian guidelines. Adjusted L_{Aeq} values are unacceptable under both sets of guidelines for both periods of the day (table 7).

Statistical analysis of the individual sample sites using Kruskal – Wallis tests provides evidence that in both sample areas there is a statistically different level of environmental noise either between the sample sites, or the sample time periods in either area. By conducting a Mann-Whitney analysis on the difference between the median values for the two sample areas, the test is significant at a value of 0.0002. This provides enough evidence to reject the null hypotheses that the median values of the sample areas are equal and identifies a statistically significant difference in the amount of environmental noise between the two study areas. This statistical evidence supports the hypothesis that the built environment affects the level of environmental noise to which residents are exposed. A Levene's test of equality of error variances also supports this hypothesis, by showing that both sample areas and sample sites are significant factors in the variance with an R squared value of 0.477 (figure 18).

Table 7. L_{Aeq} and Adjusted L_{Aeq} values compared to EPA and Italian SPL levels permitted for health safety

	Health values	Area 1	Area 1	Health values	Area 2	Area 2
		unadjusted L_{Aeq}	adjusted L_{Aeq}		unadjusted L_{Aeq}	adjusted L_{Aeq}
	Urban Residential			Predominantly commercial		
EPA Values						
Day 07:00-22:00	52	60.8	61.5	65	64.9	66.2
Night 22:00-07:00	45	58.2	66.7	60	57.9	66.9
	Residential Areas			Areas of intense activity		
Italian Values						
Day 06:00-22:00	55	60.5	61.2	65	64.5	65.9
Night 22:00-06:00	45	58.6	68.2	55	57.8	67.3

Tests of Between-Subjects Effects

Dependent Variable: adjlaeq

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1068.259[a]	6	178.043	6.224	.000
Intercept	177523.850	1	177523.850	6205.429	.000
area	576.160	1	576.160	20.140	.000
SampleSite	492.099	5	98.420	3.440	.011
Error	1172.921	41	28.608		
Total	179765.030	48			
Corrected Total	2241.180	47			

a. R Squared = .477 (Adjusted R Squared = .400)

Figure. 18 Levene's test of equality of error variances demonstrating that both the study area and sample site are significant factors in the data point variance.

6. LIMITATIONS, RECOMMENDATIONS AND CONCLUSIONS

The objective of this research is to observe and report on variations in environmental noise with respect to built environments and temporal change. Two areas representative of different types of land use were compared, looking at spatial variability of environmental noise within and between sample areas. This study provides information regarding land use planning decisions, the resulting pollution and the possible health implications for residents.

Study results indicate higher levels of environmental noise occur in mixed-use neighbourhoods when compared to predominantly residential neighbourhoods. The variability in environmental noise between the two study areas is a result of increased vehicular and pedestrian traffic as well as background noise generated by institutional and industrial noise like delivery trucks, and ventilation systems.

The variability of environmental noise is statistically significant within each sample area between sample points, between the two study areas and temporally. Kruskal-Wallis tests were used to examine differences in levels of environmental noise within the sample area and presented enough evidence to reject the null hypotheses that all sites had equal amounts of sound at a confidence level of 95%. As well, using a 2-sample Mann-Whittney test to examine the variation in sound between the two sample areas also presented enough evidence to reject the null hypotheses that the median values of the different areas at a confidence level of 95%.

Inside study Area one, environmental noise varied between sites as a result of traffic patterns. Sites that were near high traffic roads with heavy truck or bus traffic exhibited higher levels of environmental noise than more distant sites. Area one was also vulnerable to disturbance as a result of traffic because of the lower levels of background noise allowing the traffic to be more disruptive. Area two demonstrated less sample site variation in environmental sound with sites near high traffic roads and bus routes recording higher levels of sound. The variation was less than within Area one because there were higher overall levels of traffic and greater background noise.

In Area one the absolute environmental noise levels were in the range of an office environment or a normal conversation which is considered to be comfortable for humans. Area two the absolute environmental noise levels were higher and can be considered intrusive for normal conversation and slightly annoying. For both study areas the peak noise events ranged from annoying to very annoying and obscured conversation.

Un-adjusted L_{Aeq} levels of environmental noise exceeded EPA and Italian guideline values for human health impacts in Area one during the daytime. Area one exceeded the Italian guideline values by 5.5 dB (A) during the day and 13.6 dB (A) and the EPA guidelines by 8.8 dB (A) during the day and 13.2 dB (A) at night. Area two Un-adjusted L_{Aeq} were acceptable at all times except at night under the Italian guidelines where it was 2.8 dB (A) over guidelines. Adjusted L_{Aeq} values were unacceptable by both sets of guidelines at all times.

Results of this study are not necessarily representative for all areas of the city as a result of limitations placed on the study. Limitations include both financial and time constraints, equipment used for this study was lower quality than international standards due to financial constraints, and sampling areas and times were also limited to two areas and for a short temporal frame as a result of man-power limitations. An increase in the number of study areas across additional land-use types in Halifax would provide a more complete understanding of the relationship between environmental noise, built environment and human health risks. Sampling throughout the year would also reduce the influence of seasonal variation of environmental noise levels as well full 24 hour samples would also remove measurement error implicit in L_{Aeq} calculation.

Further study of environmental noise should be carried out in order to fully understand the health risks to which residents of Halifax are exposed   Future research should incorporate a more comprehensive sampling strategy looking at different areas of Halifax and other land use types and should be complimented by solicitation of perceived noise health impacts among neighbourhood residents. Seasonal variation should also be examined as the source and character of environmental noise may change due to weather and road condition changes.

Planning changes should also be undertaken to route heavy traffic to avoid residential areas or sensitive areas like schools. City buses, a powerful noise source, should be required to improve on muffler quality and Halifax should look to adopt environmental noise standards in order to protect the health of both residents and the quality of the urban environment.

7. REFERENCE LIST

(1) Northridge ME, Sclar ED, Biswas P. Sorting out the connections between the built environment and health: a conceptual framework for navigating pathways and planning healthy cities. Journal of urban health 2003; 80(4):556.

(2) Jackson RJ. The impact of the built environment on health: an emerging field. Am J Public Health 2003; 93(9):1382-1384.

(3) Coensel BD, Muer TD, Yperman I, Botteldooren D. The influence of traffic flow dynamics on urban soundscapes. Applied Acoustics 2004; 66:175-194.

(4) Passchier-Vermeer W, Passchier WF. Noise Exposure and public health. Environmental Health Perspectives 2000; 108(1):123-131.

(5) Regecová V, Kellerová E. Effects of urban noise pollution on blood pressure and heart rate in preschool children. Journal of Hypertension 1995; 13:405-412.

(6) Stanfeld SA, Berglund B, Clark C, Lopez-Barrio I, Fischer P, Öhrström E et al. Aircraft and road traffic and children's cognition and health: a cross-national study. Lancet 2005; 365:1942-1949.

(7) Babisch W, Beule B, Schust M, Kersten N, Ising H. Traffic noise and risk of myocardial infarction. Epidemiology 2005; 16(1):33-40.

(8) Seto ETW, Holt A, Rivard T, Bhatia R. Spatial distribution of traffic induced noise exposures in a US city: an analytic tool for assessing the health impacts of urban planning decisions. International Journal of Health Geographics 2007.

(9) World Health Organization (WHO). Occupational and community noise. Fact scheet N.258 . 2001. http://www.who.int/mediacentre/factsheets/fs258/en/print.html

(10) Staff. Regional Municipal Planning Strategy. 2007. http://www.halifax.ca/regionalplanning/documents/Regional_MPS.pdf

(11) Zhang X, Chen J, Tan M, Sun Y. Assessing the impact of urban sprawl on soil resources of Nanjing city using satellite images and digital soil databases. CATENA 2007; 69(1):16-30.

(12) Bengston DN, Potts RS, Fan DP, Goetz EG. An analysis of the public discourse about urban sprawl in the United States: Monitoring concern about a major threat to forests. Forest Policy and Economics 2005; 7(5):745-756.

(13) Frenkel A. The potential effect of national growth-management policy on urban sprawl and the depletion of open spaces and farmland. Land Use Policy 2004; 21(4):357-369.

(14) Stone J. Urban sprawl and air quality in large US cities. Journal of Environmental Management 2008; 86(4):688-698.

(15) Wu J. Environmental amenities, urban sprawl, and community characteristics. Journal of Environmental Economics and Management 2006; 52(2):527-547.

(16) Couch C, Karecha J. Controlling urban sprawl: Some experiences from Liverpool. Cities 2006; 23(5):353-363.

(17) Eid J, Overman HG, Puga D, Turner MA. Fat city: Questioning the relationship between urban sprawl and obesity. Journal of Urban Economics 2008; 63(2):385-404.

(18) Hancock T. Health and sustainability in the urban environment. Environmental Impact Assessment Review 1996; 16(4-6):259-277.

(19) Mielke HW, Gonzales CR, Smith MK, Mielke PW. The Urban Environment and Children's Health: Soils as an Integrator of Lead, Zinc, and Cadmium in New Orleans, Louisiana, U.S.A. Environmental Research 1999; 81(2):117-129.

(20) de Hollander AEM, Staatsen BAM. Health, environment and quality of life: an epidemiological perspective on urban development. Landscape and Urban Planning 2003; 65(1-2):53-62.

(21) Mosskov JI, Ettema JH. Extra-auditory effects in long-term exposure to aircraft and traffic noise. Occupational and Environmental Health 1977; 40:177-184.

(22) Piccolo A, Plutino D, Cannistraro G. Evaluation and analysis of the environmental noise of Messina, Italy. Applied Acoustics 2005; 66:447-465.

(23) Arafa MH, Osmon TA, Abdel-Latif IA. Noise assessment and mitigation schemes for Hurghada airport. Applied Acoustics 2007; 68:1373-1385.

(24) Sommerhoff J, Recuero M, Suárez E. Community noise survey of the city of Valdivia, Chile. Applied Acoustics 2004; 65:643.

(25) Morillas JMB, Gómez Escobar V, Mèndez Sierra JA, Vilchez Gómez R, Trujillo Carmona J. An environmental noise study in the city of Cáceres, Spain. Applied Acoustics 2002; 63:1061-1070.

(26) Brown AL, Lam KC. Urban noise surveys. Applied Acoustics 1987; 20:23-39.

(27) International Standards Organization. ISO 1996 - Acoustics - description, measurement and assessment of environmental noise - part 2. Second. 2007. Switzerland, International Standards Organization, (ISO).

(28) El Fadel M, Chahine M, Baaj H, Mezher T. Assessment of noise impacts at airports. International Journal of Environmental Studies 2002; 59(4):447-467.

(29) Leong ST, Laortanakul P. Monitoring and assessment of daily exposure of roadside workers to traffic noise levels in an Asian city: a case study of Bangkok streets. Environmental Monitoring and Assessment 2003; 85:69-85.

(30) Miedema HME, Oudshoorn CGM. Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. Environmental Health Perspectives 2001; 109(4):409-416.

(31) Gaja E, Gimenez A, Sancho S, Reig A. Sampling techniques for the estimation of the annual equivalent noise level under urban traffic conditions. Applied Acoustics 2003; 64:43-53.

(32) Ng CH, Tang SK. On monitoring community noise using arbitrarily chosen measurement periods. Applied Acoustics 2007.

(33) Environmental Protection Agency (EPA). Environmental Noise. 2007. http://epa.sa.gov.au/pdfs/info_noise.pdf

(34) World Health Organization (WHO). Guidelines for Community Noise. 1999. http://www.who.int/docstore/peh/noise/guidelines2.html

(35) International Standards Organization. ISO 1996 - Acoustics - description, measurement and assessment of environmental noise - part 1. Second. 2003. Switzerland, International Standards Organization, (ISO).

(36) DMTI. Land use and City Roads, Halifax NS. Maps & Geospatial Information Collection, Dalhousie University. Markham, Ontario. 1-9-2007.

(37) Center Technology Corp. Instruction manual for Center 322 data logger sound level meter. 2006.

(38) Marantz. Marantz professional portable solid state recorder, model PMD660 user guide. 2005.

(39) McDonald JH. Handbook of Biological Statistics. University of Delaware . 5-1-2008. http://udel.edu/~mcdonald/statkruskalwallis.html

(40) Heckert A. Levene Test. National Institute of Standards and Technology . 4-4-2003. http://www.itl.nist.gov/div898/software/dataplot/refman1/auxillar/levetest.htm