Noise level variation in the CBD with height

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ABSTRACT

Traditionally noise measurements are taken on a horizontal plane, largely ignoring the vertical propagation. This vertical propagation is of particular importance in the CBD as it is characterised by high rise offices where workplaces are often exposed to noise generated from traffic jams. These excessive noise levels could lead to interference with communication or cause distraction as well as several other health problems. To study the vertical noise propagation, a suitable area within the CBD was selected, of which, a simulated model was created. Results from the simulation were verified with real world noise level measurements, which showed a 6 dB(A) decay over the first 50 m of height, and a maximum decay of 4 dB(A) at heights over 50 m up to 140 m.

INTRODUCTION

Within modern day societies, noise, traditionally regarded as unwanted sound, has become an ever present problem to the community. In the developing countries where the manufacturing industry is heavily utilised for the benefit of infrastructure, a higher proportion of population are at risk of exposure to excessive levels of noise when compared to a more developed country in a post industrial era (Alberti, 1998). As exposure to this problem increases as the world continues to develop, further studies into the propagation of noise and its effects are required. Some adverse effects of exposure to excessive noise levels, whether that stems from industrial, aviation or traffic noise, have been documented to show auditory and extra auditory health risks. These risks can range from a minor annoyance or distraction, to increased stress levels, communication disruptions, hearing loss or cardiovascular strain (WHO, 1999).

In Hong Kong which is characterised by its dense and rapidly growing population a survey conducted by Wong et al (2002) found that 55% of the respondents believed that traffic noise was the major contributor of all noise. This result combined with Moura-de-Sousa and Alves' (2002) study which showed that noise levels within close proximity to local and major roads regularly exceeded noise level guildlines set out by the city of Sao Paolo Brazil. This paints an alarming picture in an environment such as the CBD, where Hong Kong's high density characteristic and large traffic volumes are present. With almost every major community at risk as countries develop, steps need to be taken to mitigate this pressing danger.

EXPERIMENTAL METHOD

Location selection

As the vertical propagation of noise is largely ignored in traditional measurements, the aim of this study was to investigate this propagation and possibly determine a general trend. To conduct this investigation, a suitable location within the Sydney CBD needed to be selected. This study area required structures that were of significant height that were in close proximity to major roads as to maximise results from the data collected. Ideally, a series of standard cases such as a lone high rise, or a canyon between two rows of high rises, given the restrictions in available locations, a suitable alternative was chosen. World square, being situated on the corner of a couple of the busiest and most congested main city roadways, Liverpool St and George St in Sydney is an ideal location for the study due to the extremely high volume of traffic flow, the high rise architectural design and relatively low-lying surrounding topography. The experiment was able to provide further data when extending the area of interest by another one block radius, allowing for a more comprehensive simulation to be built. The simulation results will later be compared to the noise measurements taken from the corresponding real world location.

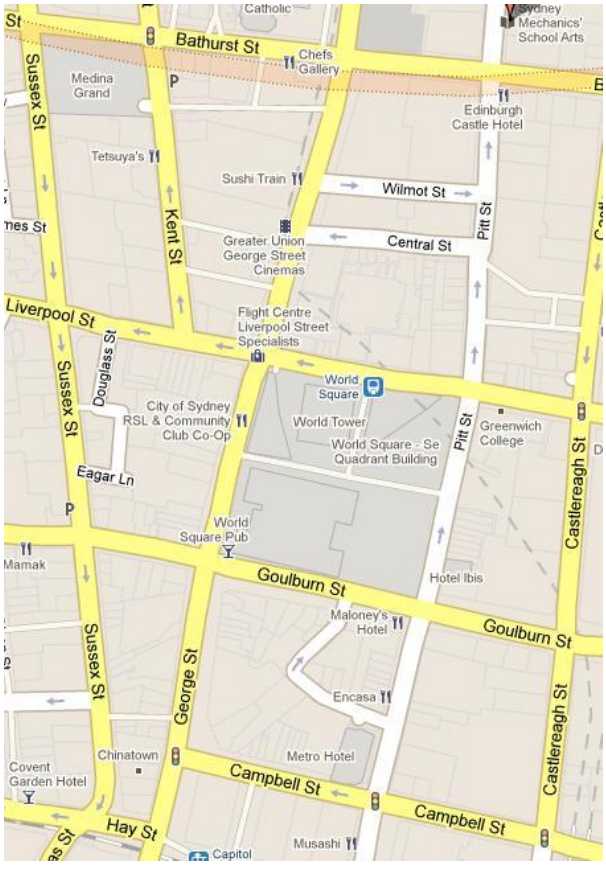

Figure 1: Selected study location

Simulated model construction

CadnaA from DataKustik, was used to create the simulation, which utilised images from Google Earth, to ensure accurate placement of structures within the model. Dimensions of each structure were obtained using a combination of measurements from a laser range finder and trigonometry. Once all the structures within the study area were constructed, the roads were created, approximately following the roads available on the base image provided from Google Earth.

Within CadnaA roads are considered noise sources, as such this is appropriate for the study, as traffic noise is one of the major contributors of noise in the CBD. The amount of noise generated by these sources is determined by the amount of traffic flow over a given period. According to the New South Wales industrial noise policy, a day is split into three time periods, day, evening and night. Using traffic volume data provided by the New South Wales Roads and Traffic Authority, the peak hour times for each daily period were determined to occur at 0800, 1700 and 2000. Since the traffic volumes during these periods were often the maximum traffic volumes over the period of an hour, the traffic volumes used in the model provide an idea about the noise levels under the worst possible conditions. However, the data set utilised did not provide hourly traffic volumes for the roadways within the study area therefore, traffic volumes for these streets were estimated from nearby roads which had similar daily total volumes.

Receivers were then placed on the three major high rise structures of World Square block, which were, World Tower Apartments, Ernst & Young office and Rydges Hotel. These receivers were placed along the street side facade of the building at least 1.5 m from the ground and less than 1 m from the top of the building in accordance with Australian Standards. In addition to these, receivers were placed on each corner of the World Square block, with auxiliary facade receivers on Summit Apartments, across George St from World Square. While these receivers only measured noise levels at specific locations within the model, the “grid” and “building facade map” functions within CadnaA were used to develop noise level contours in and around the study area, as well as on the facades of each modelled structure. As the name of the functions imply, the contour maps are developed by creating a grid of equally spaced receivers, where the ground contour map utilised a grid of 10 m x 10 m, and the facade maps, a 3 m x 3 m to approximately match the spacing between each level of a building.

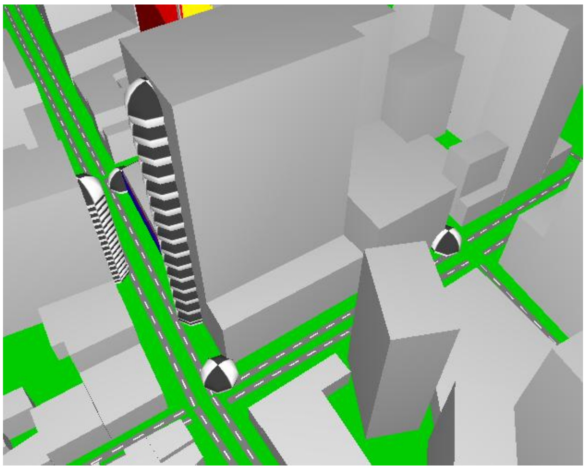

Figure 2: Ernst & Young high rise model with receivers

The calculation algorithm used by CadnaA to predict noise levels is the Calculation of Road Traffic Noise (CRTN). Developed by the Department of the Environment in the United Kingdom, CRTN takes into account series of properties of the environment such as, traffic speed, gradient and road surface, before creating a basic noise level. With this basic noise level, a series of corrections are applied depending on the complexity situation. To be able to compare the predicted noise levels from CadnaA, and real world measurements, a correction of 1.7 dB to take into account Australian conditions (ARRB – NAASRA Planning Group 1982) will be applied to all predictions, while a correction of 2.5 dB will be applied to all facade predictions to account for effects of reflection.

Noise level measurements for model verification

To verify the validity of the predictions from the simulation, real world noise measurements were taken at the corresponding location. These noise level measurements were taken using a Cesva SC310 type 1 integrating sound level meter which was calibrated using a B&K Type 4231 Sound level calibrator to 94 dB at 1 kHz in accordance with AS1259.2. Prior to and after performing each measurement, the aforementioned calibration was repeated to ensure the validity of the results, as prescribed in AS1055. The sound level meter was then placed in a weather proof case with the attached microphone positioned 1.5m above the case, again to conform with AS1055. However, due to access restrictions, only street level measurements were compared, as facade and roof measurements could not be taken. Due to the high amount of pedestrian traffic during the peak hour periods, the location of equipment was placed in a non-obstructive location, but still within 10 m radius of the locations within the simulated model. To minimise obstruction to the flow of pedestrian traffic, the sound level meter was placed close to a facade at each location, but no closer than 1 m, as set in Australian Standard guidelines. As such, these real world noise level measurements will require a correction of -2.5 dB to remove the effects of reflection.

VERTICAL NOISE PROFILE AND VALIDATION

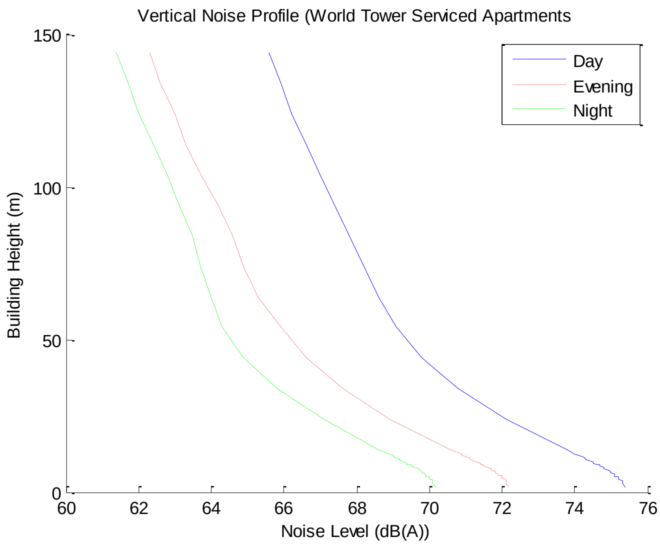

Figure 3: Vertical noise profile of World Tower

In figure 2 above, the vertical noise profile of World Tower Serviced Apartments is shown. Similar behaviour was displayed across all building facades, across all peak hour periods, where over the first 50 m in height, there was an approximate decay of 6 dB(A). This result showed a relatively large disparity when compared to Allen's (2010) study which presented a 2 dB(A) decay over a height of 47.7 m. In contrast to this, the study presented by Alam et al (2009) displayed a result where, noise level decay varied between a range of 3.7 to 12.8 dB(A) over heights between 43 and 46.5 m. Heights over 50 m displayed a slower rate of decay, which is quite contrary to what was expected, as the exposure to more noise sources increase with height, although this could be attributed to the slower decay in noise levels at increasing heights.

In the table 1 below, a discrepancy can be seen between the predicted and measured values. The measured values at each corner tend to be lower than those of the predicted by a slight margin, while the measurements and predictions at Summit Apartments are an exception, with values higher than the predicted levels. These discrepancies had an average of approximately 3 dB(A).

Table 1: Comparison of predicted and measured noise levels

Goulburn/ George	measured	predicted	difference
800	74.5	78.3	3.8
1700	73	74.4	1.4
2000	72	74.4	2.4
George/Liverpool			
800	74.5	76.4	1.9
1700	80.5	73.1	7.4
2000	76.5	72.8	3.7
Liverpool/Pitt			
800	72.5	75.5	3
1700	70.5	72.4	1.9
2000	72	70.2	1.8
Pitt/Goulburn			
800	72	77	5
1700	71	73.1	2.1
2000	72	71.8	0.2
Summit			
800	78.5	75	3.5
1700	75	71.5	3.5
2000	75	71.9	3.1

POSSIBLE FACTORS AFFECTING RESULTS

Model construction

Since the model of the study area was the basis of the predictions, the accuracy within placement of the structures and roads was essential. Overlays placed on the base map, to increase precision on the locations of structures, were positioned accurately with the aid of Google Earth utility. Dimensions of each structure within the study area were made by hand with the laser range finder possibly introducing the factor of human error; however the overall dimension of the structures would not have played a major role in affecting the end prediction. As the model considered was simple with a flat façade, it did not accurately represent the physical dimensions of the actual structure. As a result, awnings that are often used as noise barriers to prevent noise propagating vertically were neglected. Major changes in architecture such as an apartment tower being offset further away from the road than the street front were modelled as solid structures possibly skewing the results. Although this "solid structure" assumption may have resulted in a less accurate prediction, the assumption of each structure having a flat façade, ignoring finer details such as window recesses and balconies, would not have significantly increased the accuracy of the predictions provided by the simulation.

Traffic flow

As traffic flows were the sources of noise within the simulation, correct traffic flow data was of critical importance to the model. However, direct traffic data for the roads within the study area were not available; thus, they were estimated from nearby streets with a similar daily traffic volume. Aside from this, the traffic data used to estimate the values used in the model was from 2005 as a newer data set had not been made available the general public. Since an older data set was used, it does not take into account the potential growth in traffic in the last six years. In spite of this, the predicted noise levels were slightly higher than that of the measured levels. This may have been due to the fact that, traffic lights were not used within the model, which meant that traffic was free flowing and not stationary as is often the case during peak hour traffic jams on major thoroughfares. This is significant as the traffic is essentially a point source when the traffic is stationary. Whereas when the traffic is free flowing, it is characteristically a line source. This circumstance could potentially account for the large difference in results as a point source will have a 6 dB decay in doubling of distance, while a line source will only decay by 3 dB. This issue of stationary vs. moving traffic is also an issue when applying the CRTN algorithm for predicting noise levels. One of the primary factors for CRTN predictions is the speed of which the traffic flows taking into account the noise generated by road-tyre interaction. Since the traffic during these peak hour periods is moving at a significantly reduced speed when compared to the speed limit, this noise factor in the real world would be largely negligible compared to the CRTN predictions generated by the simulation.

Streets within the study area were largely one way streets with only George St and Goulburn St being the only 2 two way streets. As there were several one way streets, during each peak hour period, the usage of certain roads will vary depending on the direction the roads allow. This is reflected in the results were the highest measured noise level was on the corner of George St and Liverpool St during the evening peak hour, most likely due to the common usage of Liverpool St by commuters returning home via the Sydney Harbour Bridge. This result compared to the peak predicted level on the corner of George St and Goulburn St, where the 2 two way roads intersected.

Road usage is also raised with the matter of traffic volume estimation, as although data for nearby streets was used to estimate the traffic volumes for the desired roadways, the usage of the known roadways could differ greatly to that of the major thoroughfares of those within the study area. This can be seen in the results where there is a large difference between the predicted and measured noise levels.

Real world measurements

Although there were several factors affecting the predicted result of the simulation, various factors could also have affected the measured result. As the measurements were made at street level during the peak hour periods, the evening and night time periods had a high volume of pedestrian traffic. This could've affected the results as people could have been having loud conversations as they walked by.

As mentioned previously, the presence of traffic lights could play a role in explaining the discrepancy between measurement and prediction, as they affect the flow of traffic. This is also true for the pedestrian flow, as the sound level meter was close to an intersection at each location, where the build up of people waiting to cross the road could add to the noise measured. Other influences could have been the monorail that runs down Liverpool St and various city life events, such as performing buskers, car alarms, emergency vehicles rushing to an incident or modified cars passing by.

As noted in the results, Summit Apartments presented the peak measured noise levels for two of the three peak hour periods. This was most likely due to the low awning covering the pedestrian walk way causing high levels of reflection to be recorded. This particular location was also within close proximity to the bus lane which could have severely affected the measurements as several amounts of heavy vehicles, mostly buses, passed by not more than 5 m away from the sound level meter.

The noise level descriptor L_{A10} is a statistical descriptor that represents the noise level that is exceeded for 10% of measured time. This means that the longer the duration of a sample the more accurately the descriptor can define the recorded sample. With the limitation of equipment and man power, measurements could not be taken at each location simultaneously, therefore they were taken sequentially around the peak hour period in 15 minute samples. This short measurement sample time, compared to the CadnaA predictions, which use peak hour values that represent an hour long sample could account for the difference in results.

CONCLUSION

With the adverse health effects associated with exposure to excessive levels noise well documented, it is important to thoroughly investigate all aspects of the propagation of noise. Measuresurements presented a peak level of 80.5 dB(A) and a predicted decay of 6 dB(A) over the first 50 m of height, with a further maximum of 4 dB(A) up to heights of 140 m. Although the predicted results showed that the noise levels were of a safe level, further investigation should be undertaken to verify and validate this result. These investigations should take into account all factors to ensure the accuracy of the predictions, and to consider taking real world façade measurements to validate the vertical noise profile generated by the simulation.

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