Spatial Resolution for Modelling of Noise in Urban Areas

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ABSTRACT

Modern instrumentation utilises internet connectivity and cloud based technology to allow for large scale and long term noise monitoring programs making them easier and simpler to perform. The data acquired during monitoring projects can be utilised for acoustic modelling of different areas to produce strategic noise maps for wide range of applications. Accurate assessment of noise for large urban zones may require substantial computational resources or processing time. Acoustic modelling can be performed within a shorter time frame if spatial resolution for the area is reduced. This may be a detriment to the accuracy of the modelling but reduces the required computational resources.

The paper is intended to provide recommendations on modelling resolution that can be used for assessing noise in an urban environment. These recommendations are derived from modelling performed for large scale strategic noise monitoring programs. The paper details assessment of the modelling accuracy for different sized modelling grids in suburban and multi-story building environment. Results of the research can be used to assist in choosing acoustic modelling parameters for different urban areas.

1 INTRODUCTION

Urban densification brings sensitive receivers closer to noise sources. With plans of fitting more residential users near areas for industrial usage or heavy transportation corridors, sensitive land uses are potentially more exposed to unacceptable noise levels. Excessive environmental noise has adverse impacts on physiological and psychological systems (Ising and Kruppa, 2004). Due to this, proper understanding of noise sources and its impact is crucial to ensuring that the amenity of these sensitive uses are preserved. Noise modelling complemented by long term noise monitoring data allows for a strategic view of noise impact from all sources to inform future planning ideas and usage. The European Noise Directive (The European Parliament, 2002) envisages that European cities with population above 250,000 inhabitants will have strategic noise maps based on long term monitoring data of at least 12 months. These maps can be used for comparison with the European noise goals (The World Health Organization, 2009) or other relevant noise criteria applicable.

The South Australian Environment Protection Authority was involved with multiple long term noise monitoring projects in a wide range of urban and suburban settings (Lenchine and Song, 2016). These locations are characterised by complex noise environments unique to the area. The two monitoring programs referenced for this paper consist of monitoring in the Adelaide Central Business Districts (CBD) which would represent a typical “urban” setting; while the monitoring project in Lefevre Peninsula would represent a typical “suburban” setting.

Calculations of large scale noise maps requires significant amount of data, preparation and large processing duration. Reducing the calculation time and cost of demanding noise models increases the uncertainty in the predictions (Merchan and Diaz-Balteiro, 2013). This paper will discuss the differences in locality such as the types of buildings and types of noise expected in these urban and suburban settings. Different modelling parameters are experimented with and compared to determine the most effective parameters for the size and locality of the selected modelling area.

2 DIFFERENCES IN LOCALITY

Urban and suburban areas introduce different noise sources for sensitive uses within. Urban land use such as CBDs are affected by noise sources from mixed commercial and residential activities. Noise impact of an urban setting is largely controlled by traffic noise (Lenchine and Song, 2016) and fluctuates with the rise and fall of traffic volume. Such areas are also characterized by tall buildings and narrower streets, with less open areas such as parks. Acoustically, this means that energy from noise sources is dominantly retained within the environment and potentially travels to larger heights as it is reflected by these taller buildings, affecting more people in a small area.

Sensitive land use in suburban areas if not adjacent to industrial land use, may be affected by other sources such as rail or major arterial roads. Comparing the types of buildings in suburbs and CBD areas, buildings in suburban areas are generally one or two floor residential buildings or small multi floor units. Buildings in CBD are generally taller and have significantly larger footprints. Industrial noise sources in suburban settings may have noise sources located at relatively high altitudes and modelling should consider these elevated noise sources. Substantial industrial noise sources are normally not expected in a CBD locality. Similarly, road and rail noise may travel over significant distances and may be considered a significant noise contributor in suburban areas.

Taking these differences into consideration, it is important that modelling project parameters are selected based around the study location. The required accuracy of the results may be determined depending on the end use of the modelling results. Examples of noise modelling for strategic noise impact of an entire precinct would not require as much accuracy as noise modelling requirements when determining specific acoustic attenuation for an industry. Examples utilized for this paper would consist of similar sized blocks from the urban and suburban settings to ideally compare these examples as closely as possible. The modelling program used during this study was Soundplan version 8.0. The noise sources explored during this study include road traffic noise, railway noise and noise from industries bordering the suburban residential receivers. The size of the study area will be approximately 1 km^2. Figure 1 (a) and (b) show the target study locations for urban and suburban respectively. The difference between the two localities can be seen very clearly in these figures.

(a) (b)

Source (*Nearmap*, 2018)
Figure 1: Chosen study areas for (a) urban and (b) suburban settings

Comparing some statistics between the two localities, there were 628 buildings covered within the 1 km^2 study area of the urban locality while the suburban locality has 1072 buildings built into the model. The suburban locality has significantly lower traffic volume when compared to the urban settings (DPTI, 2015). The suburban locality only has one major arterial road (over 20,000 annual average daily traffic) branching into residential roads which further splits into small local roads. The urban locality consists almost entirely of arterial and major roads (from at least 10,000 annual average daily traffic and greater) with some small laneways between buildings.

It is difficult to estimate contribution of noise from sources such as local businesses or local music venues such as bars and pubs. Therefore these sources were left out of the overall model for this study and is assumed to be more localized than sources such as road traffic. However, contribution from larger industry sources, such as those represented in the suburban example, could be estimated with better accuracy due to significant contribution to impact in quiet areas away from road traffic noise. An estimate of the noise contribution from the industry in the suburban area was included into the model.

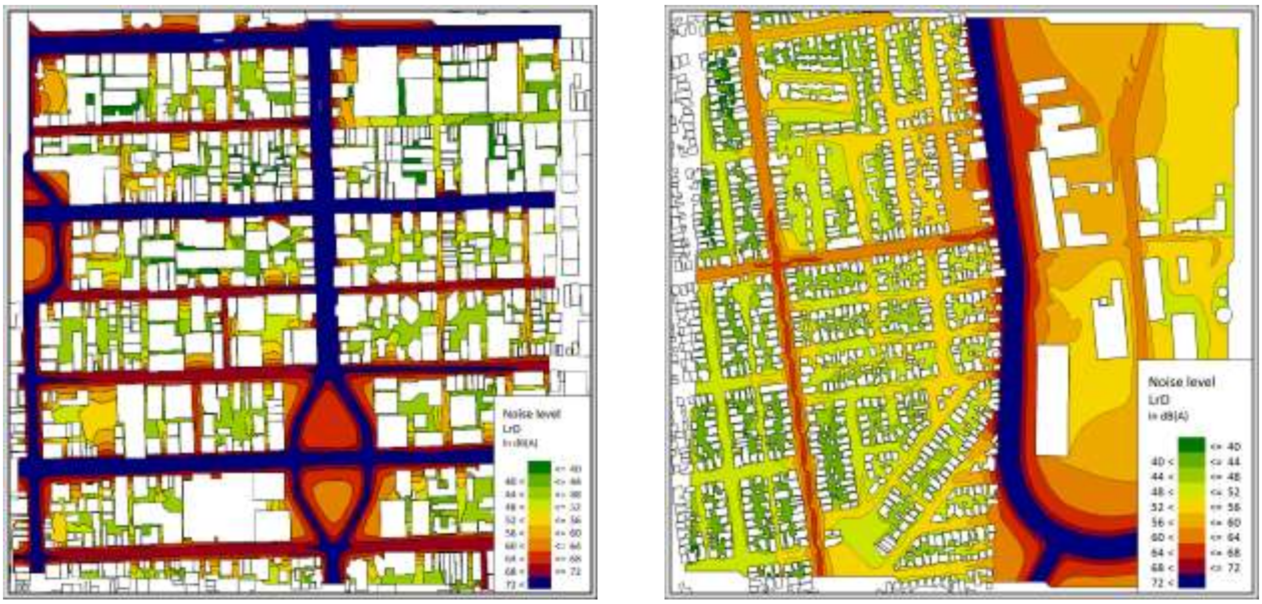
3 Computing Grid Noise Maps

The time required to complete the calculation process will be used as the main measure to compare the computational examples. The time elapsed should only be representative for this paper and would likely be significantly different for different alternative computational hardware.

When the study areas are calculated under the same modelling parameters, the time elapsed for suburban locality modelling was more time consuming when compared to the urban setting, likely due to the increased number of buildings in the suburban locality. The acoustic parameters used are noted as below in Table 1, these settings would then be used as the benchmark of comparison for other changes in the set up. Figure 2 shows the grid noise map results for this benchmark calculation. All calculation results are represented in A-weighted equivalent sound pressure levels. Other weightings were deemed unnecessary as A-weighted levels were generally well correlated with other representative weightings (Song and Lenchine, 2017). These results were calibrated to long term noise monitoring data and were found to be approximately ±2dB at monitored locations

Table 1: Benchmark acoustic modelling parameters

Parameter	Value	
Façade Reflections Considered	0	
Source Search Radius	1000m	
Tolerance	0.5dB	
Grid Space	10m	
Height above ground	1.5m	
Time Elapsed	Urban 1 Hour	Suburban 1 hour 20 mins



(a) (b)

Figure 2: Benchmark grid noise map results

3.1 Grid Space Setting

The grid space setting determines the resolution of the grid noise map and is one of the significant drivers of the elapsed time and the number of data points required to be calculated. For the benchmark calculations the gird space setting was set to 10m (10m x 10m or 100m^2 grids), which is approximately 0.01% of the total study area. This translates to approximately 10,000 nodes required to be calculated. Increasing the grid space setting to 31.6 m brings the grid element to approximately 0.1% of the total study area. This means that only 1,000 nodes were required to be calculated, reducing the resolution of the grid noise map significantly. Similar comparisons were undertaken for the suburban locality. The lower resolution models took a significantly less amount of time to complete the calculation process. Figure 3 (a) and (b) shows the resulting grid noise map while (c) and (d) shows the differences between the benchmark calculation vs the lower resolution. This reduction of resolution reduced the processing time of both localities to approximately 10 minutes (over 80% reduction in calculation period).

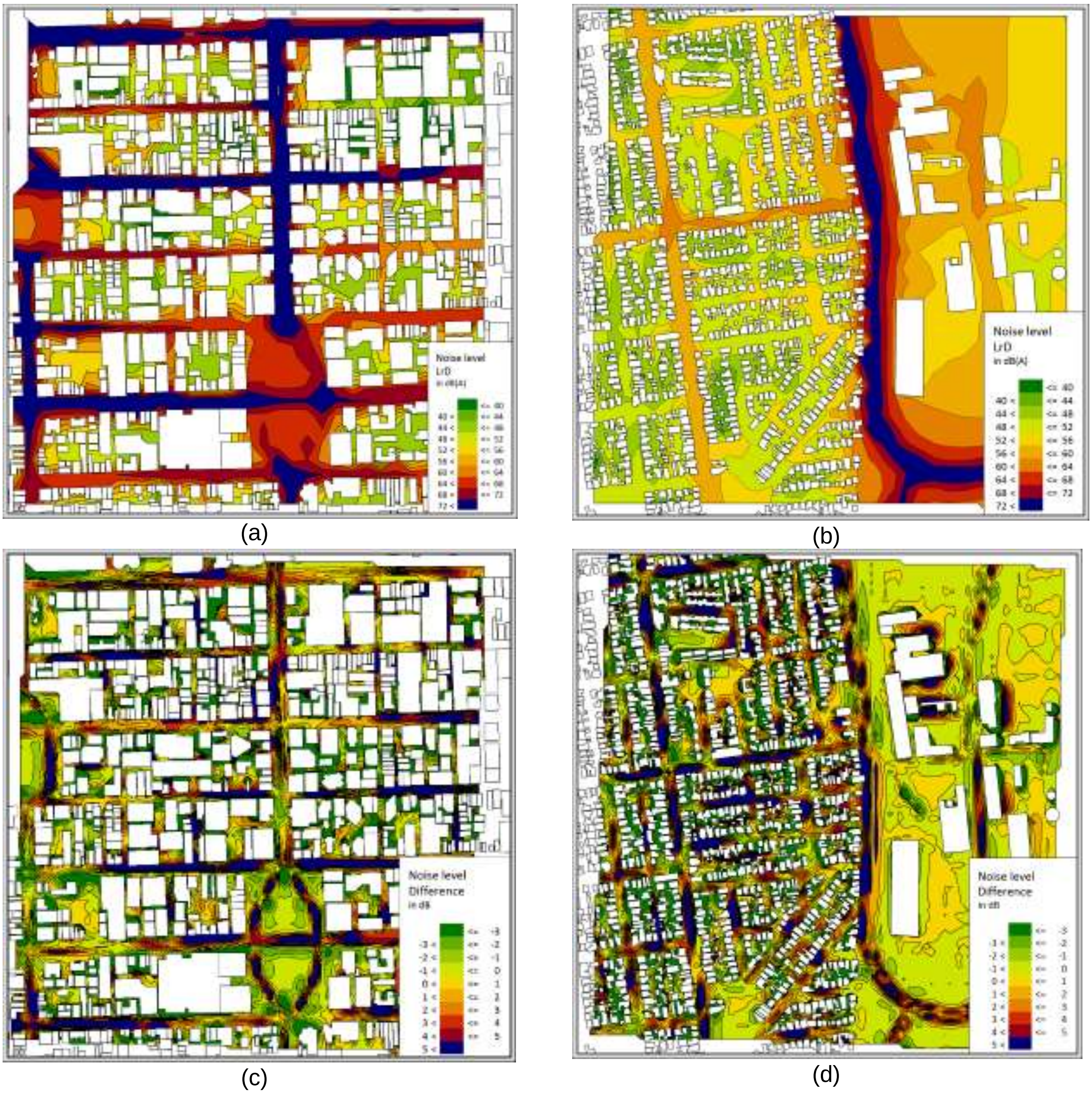


Figure 3: Results of lower resolution calculation and difference to benchmark

The lower resolution on both situations reduces the clarity of contribution from the main sources such as road and rail. The lower resolution also results in severe under estimate of noise level predictions from major noise sources by over 5dB and overestimated results in screened areas when compared to the benchmark calculation options. This is especially clear for the suburban example. Even though the processing time required was a fraction of the benchmark calculation, the inaccuracies arisen from the lower resolution may be too large.

3.2 Reflection Surface Order Setting

The inclusion of noise reflection from surfaces to the calculation set up made a substantial difference to the elapsed time required to complete the calculations for both urban and suburban localities. The number of reflection surface order considered means the number of facades or surfaces the noise would reflect of as it reaches the receiver point. For example, if 2 reflection surfaces orders are considered, it means that the ray lines from a noise source will reflect off 2 surfaces.

Adding one reflection order of noise from facades into consideration for the model increased the elapsed processing time by almost 9 times, taking over 9 hours to complete the modelling run for both urban and suburban localities. Figure 4 shows the difference in results for (a) urban and (b) suburban localities.

(a) (b)

Figure 4: Result difference comparing benchmark to one reflection surface considered

Comparing the results of these modelling to the benchmark results, the benchmark results seemingly under predicted noise levels in areas without direct exposure to the major noise sources. The magnitude of the under prediction when comparing the benchmark calculation versus this calculation with a single reflection consideration is upwards of 5dB in significantly shielded areas. There were little to no difference for predicted noise levels directly adjacent to the major noise sources. This means that the benchmark results were able to sufficiently predict the noise exposure in areas close to main noise sources affecting the receivers and therefore should be sufficient for the purpose of a large scale noise exposure modelling.

Due to the significant increase in processing time, the under prediction may not be significant enough to warrant this increase in processing time. Therefore it may be concluded that considerations for reflective surfaces should not be required to be included if almost all receivers in the area are located close to major contributors. A conservative inclusion of the 3dB penalty for areas close to the façade or in areas shielded from noise sources should be sufficient to offset any under predictions.

3.3 Other Considerations

Other considerations that may help increase the efficiency and reduce the elapsed calculation time is to decrease the search radius for noise sources from the point of calculation. Reducing the search radius from 1km to 500m significantly reduced calculation time to about 30% of the elapsed time of the benchmark calculations. Figure 5 shows the difference of the predicted noise levels for search radius 1km and 500m.

(a) (b)

Figure 5: Difference when search radius is reduced: a) CBD modelling, b) suburban area modelling

The difference in results shown in the urban locality (a) is minimal and in the range of ±0.5dB, perhaps as a result of effective screening of distant sources by taller buildings. Interestingly, the calculation with larger search radius predicts noise levels to be higher in some screened areas, however the calculated difference at these locations were less than 3dB at smaller areas when compared to the overall study area. Larger differences are noted in the suburban locality where the lower search radius under predicts noise towards the west side of the map by over 7dB. This is because the calculation points at these areas seize to consider the industrial noise source which is over 500m away. This shows that for significantly large noise sources such as the industrial noise in the example, the noise environment may still be heavily affected or controlled by this industrial site even at substantial separation distances. As noted in an earlier section, this proves that there is no ideal setting for all modelling jobs and consideration must be given when selecting modelling configurations to the specific locality and impacting noise sources, especially for suburban localities.

4 Grid Noise Maps vs Façade noise map

Grid noise maps are not the only way to represent noise exposure for a large scale monitoring job. Façade noise maps is an alternate form of depicting noise exposure for a study location. Receiver points are defined on the façade of a building. This reduces the number of points required to be calculated for a designated study area. As seen in previous sections, the more calculation points considered, the more accurate the model would be considered. However if the only the noise exposure of buildings in an area are required to be calculated, a façade noise map can be the quicker option to consider.

For the example study areas in this paper, a receiver point was defined to be in the middle of the façade. Also, a façade is required to be at least 3m in length before computation is triggered for that façade surface. For this paper, only ground level receivers are considered.

Comparing the number of points required to be calculated for the façade noise maps for the study localities, the subject site for the urban locality has approximately 3,000 points to be calculated; while the suburban locality has approximately 5800 points. The number of calculation points is significantly less when compared to the benchmark grid noise map with approximately 10,000 points for the same areas. Due to this difference, the calculation time required for the façade noise map was half the time of the benchmark grid noise maps. Figure 6 depicts a façade noise map example for the target study areas. Each receiver point is shown in the figure while the areas of the buildings were filled by the scale colour of the most exposed façade.

(a) (b)

Figure 6: Façade noise map of study areas

Benefits of utilizing façade noise maps due to the reduced number of measurement points, allows for quicker overview of the noise exposure of each building of the study site. Alongside other parameters that may be included for building objects such as building height, number of inhabitants, or number of floors on a building, a façade noise map can be used to calculate population exposure by comparing noise exposure with the included building parameters (Lenchine and Song, 2016). The façade noise map is then able to highlight hotspot areas with buildings that will require attention for noise attenuation measures. It however is not capable of showing contribution of individual noise sources such as road or rail as clearly as a grid noise map could. The elapsed time required to complete these modelling calculations were significantly lower than those required for a grid noise map.

5 Further work required

Further work may be required to be undertaken for strategic modelling of larger study areas. The modelling comparison was only undertaken in an area sized 1km^2 and only examines noise inputs based off long term noise monitoring. Other predictions such as receivers above 1.5m from the ground level may be informative for examples such as the urban localities to represent high rise apartments prevalent in CBD areas. Further testing such as comparing grid spacing to the dimensions of major screening structures should also be further considered in future works.

Studies have shown that overall environmental noise levels from long term monitoring shows existence of cycles for environmental noise (Lenchine, 2017). Possibility of modelling and predicting future noise will require these modelling processes to be repeated several times a day. Understanding the ideal settings for each acoustic setting will be required if noise prediction algorithms are to be implemented and optimized into the modelling processes.

6 CONCLUSIONS

Comparisons between several spatial resolutions and acoustical configurations were made between grid noise maps and façade noise maps discussing the advantages and disadvantages of each and also comparing the required time to complete the calculation process. It is noted that for larger noise maps, the influence of reflective surfaces is proven to be unnecessary due to the significant increase of processing time in areas directly adjacent to major sources. Grid noise space above 30m should be avoided as noticeable difference in predicted noise levels of noise sources undermined the accuracy of the prediction. Façade noise maps were quicker to complete processing and could be used as a quick run to determine high noise hotspots and other population related investigations. Further work is required to be undertaken to understand and optimize modelling computational resources if predictive modelling is to be combined with grid noise map modelling.

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