Strategic noise mapping of Adelaide CBD

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ABSTRACT
The Adelaide Central Business District (CBD) has been facing densification due to an increase in the growth of residents and business in the area. Noise is considered by the residents of the city as one of the major problems impairing the amenity within the CBD. This has raised multiple concerns such as health and sleep disturbance. Further growth of business activities and an increase in the number of residents in the city is expected in the coming years. This may lead to increased noise impact in the Adelaide CBD and adjacent areas. This paper details strategic noise mapping based on predictive modelling coupled with indications of six noise monitoring stations deployed over a long term period. The noise monitoring stations were located strategically in the northern part of the Adelaide CBD to capture noise impact from several major noise sources. This allowed for detailed analysis of noise contribution from various noise sources. Some of the CBD areas characterised by higher noise levels are targeted for comparison with population exposure descriptors and factors. The results of this study can be utilised for effective noise management and urban planning decisions to reduce noise impact in the city.

1. INTRODUCTION
The gradual increase in population density within small areas has led to the intensification of urban traffic and other activities. These effects presume that central business districts (CBDs) and other business areas are characterised by higher noise impacts. Development plans of relevant councils indicate that their priority is the increase in the number of residents living in such areas. Providing a reasonable level of acoustic amenity to the residents is recognised as an important factor to attract and retain residents in CBDs or similar areas.

The European Noise Directive (The European Parliament, 2002) envisages that European cities with a population above 250 thousand should have strategic noise maps based on long term data. These maps can then be used for comparison with the European noise goals (The World Health Organization, 2009) or other relevant noise criteria.

The Adelaide CBD is not a big area and does not have a large population living within it. However, the city council envisions a moderate growth of the city population along with a general increase in the number of residents within the Adelaide metropolitan area. Since many of the arterial routes go through the city or its boundaries, traffic volumes are expected to rise. The greater number of entertainment events being organised in the city may also contribute towards the higher noise levels present in the CBD area.

All of these require serious attention to reduce or limit the noise impact on people working or living in the CBD. The South Australia's Environment Protection Authority conducted a strategic noise monitoring project over approximately 12 months. The data have been analysed to spot zones with higher noise impact and approach the problem of noise mitigation in the CBD from the population exposure perspective.

2. HARDWARE AND METHODOLOGY
Six monitoring stations Brüel and Kjær (B&K) Type 3639 have been deployed in the northern part of the Adelaide CBD. The equipment was mounted on street lights to reduce visual impact and utilises the mains power supply to increase uptime reliability. The location of each monitoring station was chosen based on its proximity to major arterial roads in the CBD and entertainment areas. Data acquisition was performed in online mode utilising the B&K Noise Sentinel system. Noise levels and audio records were available to the community via an Internet public access website for the lifetime of the project. A fragment of the website and the locations of the monitoring stations can be seen in Figure 1. The real time noise levels were presented in the circles corresponding to the locations of the monitoring equipment.

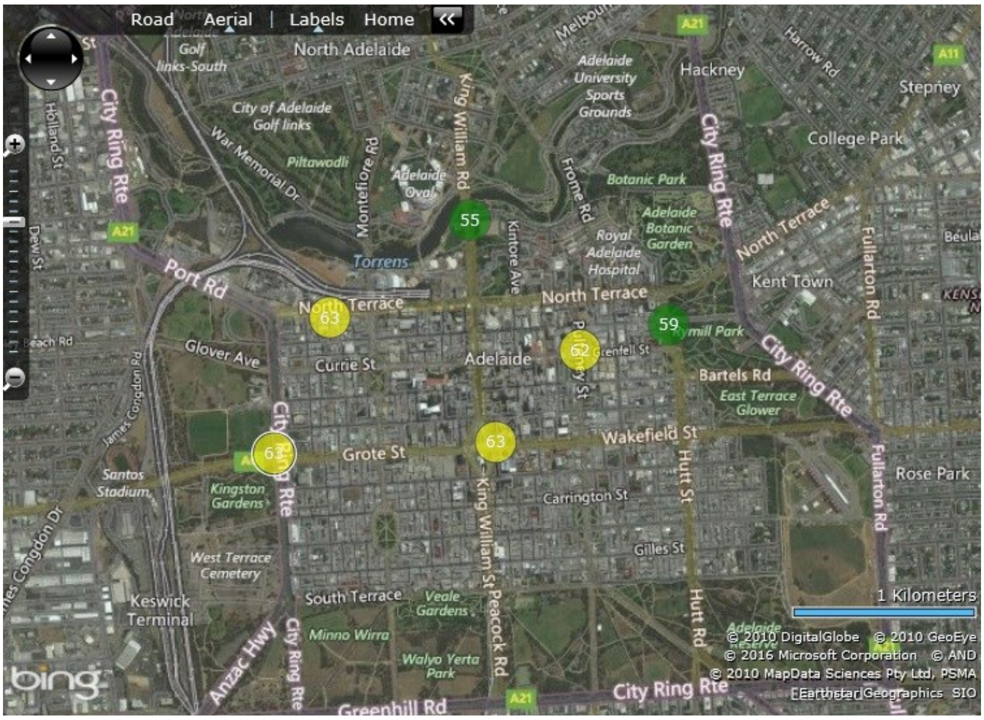


Figure 1: Locations of the noise monitoring stations in the CBD and their real time indications

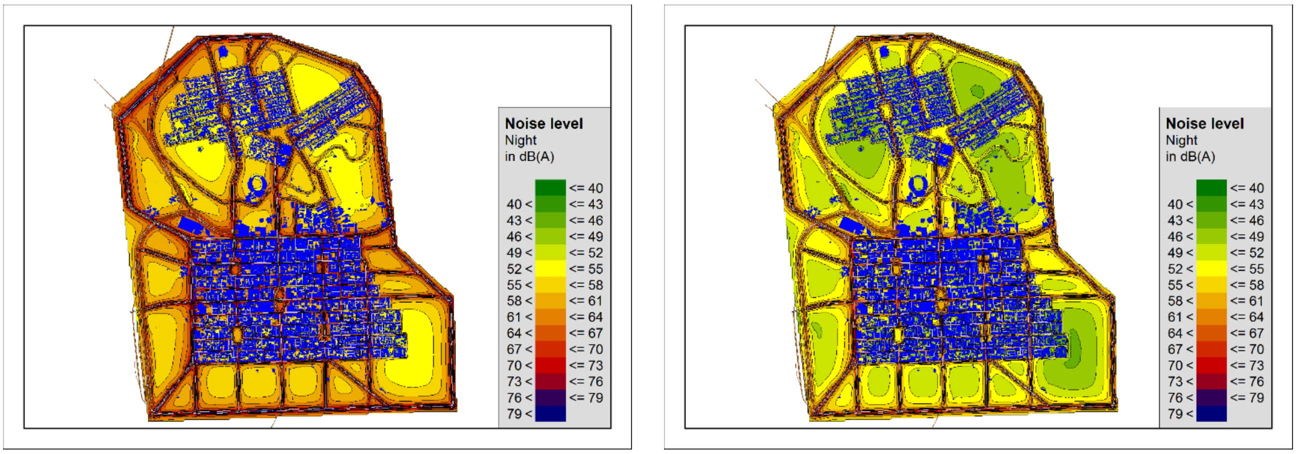
To reduce the risk of vandalism of the monitoring equipment, the measurement microphones were positioned 2.5 m above the ground rather than 1.5 m as recommended in the South Australian Environment Protection (Noise) Policy 2007. Comparative attended measurements were made at the monitoring sites at the recommended height of 1.5 m and corrections were derived and applied at the monitoring sites where necessary.

Each monitoring station was equipped with an ultrasonic wind speed and direction sensor to monitor local wind speed. The monitoring station to the west of the CBD had a 6 parameter weather sensor equipped to monitor other weather conditions such as rain, atmospheric pressure and humidity. The post-processed data set did not include periods of rain and wind speeds exceeding 5m/s.

Many of the conclusions within this paper were made based on modelling with SoundPlan. An elaborate 3D model of the CBD was created to carry out noise analysis and explore different scenarios.

3. NIGHT AND DAY TIME NOISE MAPS

Documents of the European Union are often based on day-evening-night A-weighted sound pressure levels (SPLs). L_{den} descriptor presumes penalties added to measured evening and night time levels (The European Parliament, 2002). The specification of acceptable noise levels in Australian jurisdictions is mixed and typically includes separate magnitudes for day and night as well as an evening period in relevant documents. Figure 2 shows day and night time noise maps for the Adelaide City Council area (includes CBD and North Adelaide) as per state regulations (Government of South Australia, 2007). It was calculated from the night time map that most of the CBD zone meets the interim goal of 55 dB(A) established for Europe (The World Health Organization,2009). Figure 3 features L_{den} descriptor to enable direct comparison with European quality targets and average magnitudes of the existing impact. The map indicates that many of the city areas are exposed to noise exceeding L_{den} = 50 dB(A) which is a consensus limit for high quality acoustic environment (European Environment Agency,2010). However, the average L_{den} for the Adelaide CBD does not exceed the European average of 58 dB(A) for zones away from roads with heavy traffic. The L_{den} around the North Adelaide and the south eastern parts of the CBD still show the lowest overall noise levels.



(a) (b)

Figure 2: Day (a) and night (b) strategic noise maps for the Adelaide CBD.

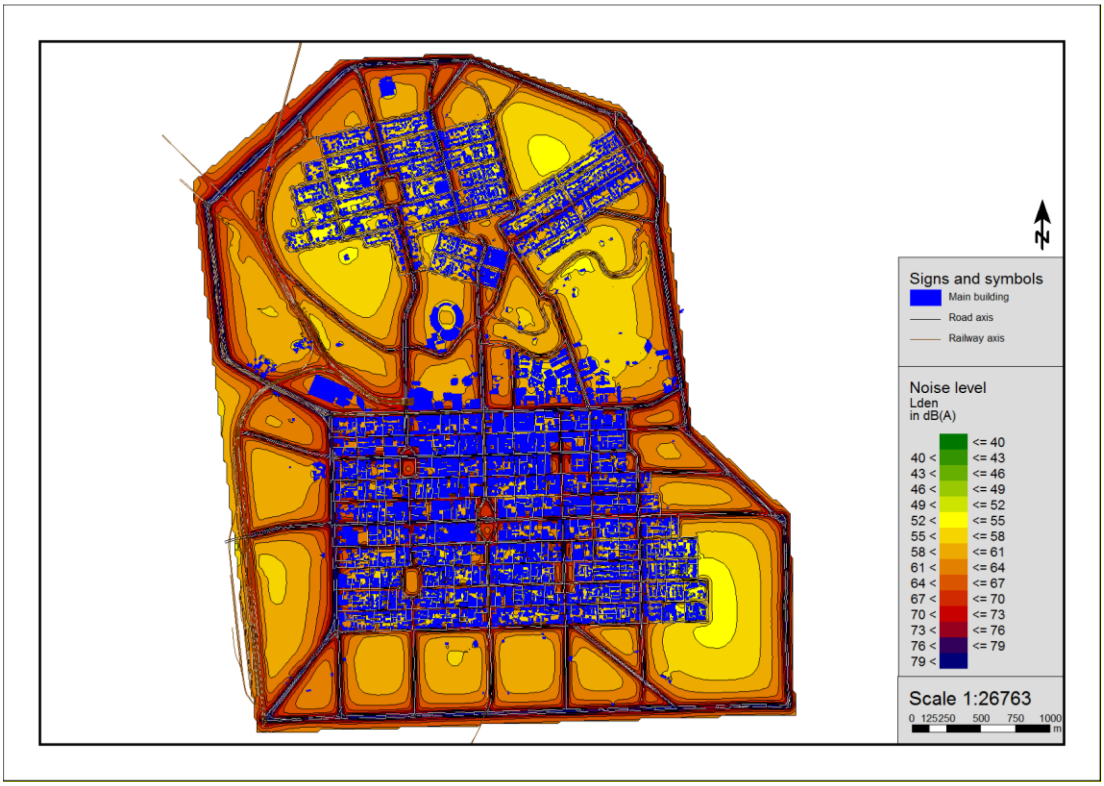


Figure 3: Day-evening-night noise levels L_{den} calculated for the Adelaide CBD.

The maps are presented for cumulative noise impact. The long term noise levels show that the Adelaide CBD has clear zones with high noise exposure and areas where SPLs are moderate and meet the requirements expected in residential areas. The major noise contributor is traffic noise from roads.

The City Council frequently authorises entertainment events in the city centre (Victoria Square) and the parklands adjacent to East Terrace. However, the noise impact from these events is well localised both in time and geographically. The noise impact from music is discussed in the following sections.

The American standard ANSI S12.9-2007/Part 5 (Acoustical Society of America, 2007) gives recommendations on the land use depending on day and night levels (L_{DNL}) which considers a 10 dB penalty to be added to the night time A-weighted levels. A substantial area in the southern part of the CBD is suitable or marginally suitable for residential developments in accordance with this standard. Practically all CBD areas with the exception of zones immediately adjacent to major roads is also suitable for residential development with limited outdoor use if sound insulation measures are implemented in the buildings (Figure 4). It should be noted that the American Standard has a relatively high L_{DNL} limit of 75 dB(A) for these zones (compatible with the sound insulation implemented).

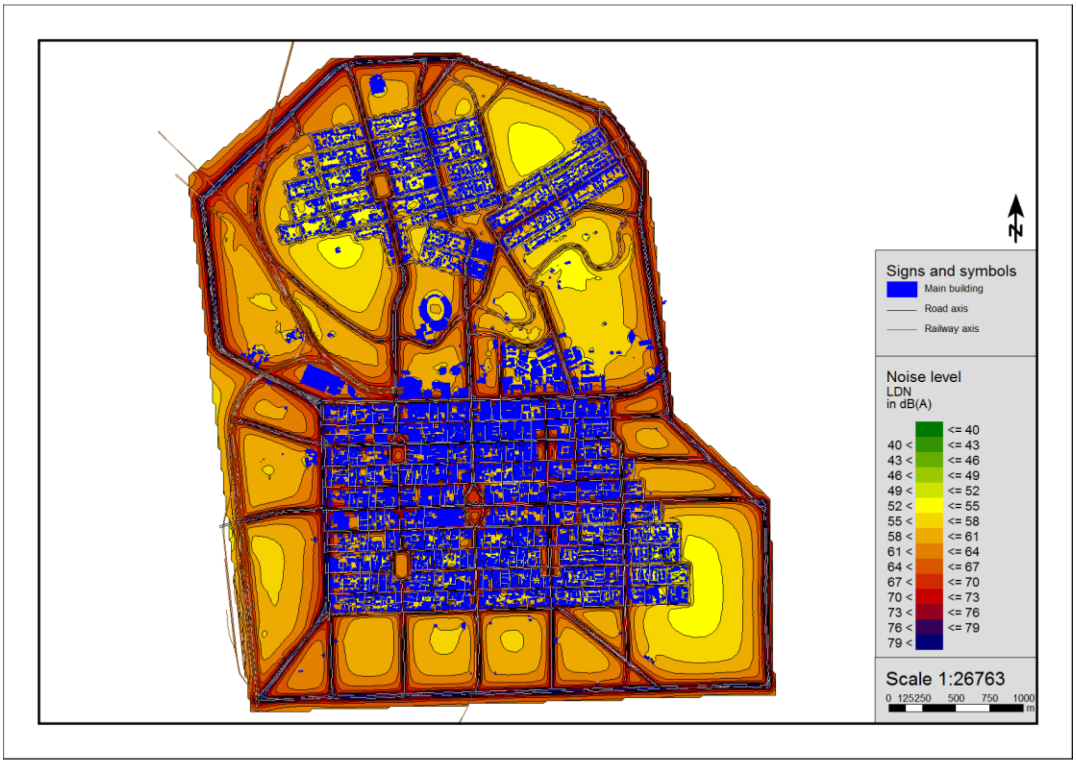


Figure 4: Noise map for the Adelaide CBD, computed day and night level L_{DNL}

4. CONTRIBUTION FROM MAIN SOURCES

4.1 Transport noise

Transport noise is the principal factor influencing the distribution of noise levels in the CBD. Rail operations affect only a minor area in the north of the CBD and western parts of North Adelaide. Rail corridors leading to the central station circumvent the city and are separated from the CBD by the parklands. Tram services through the city are performed by modern electric vehicles operated at low speed. These services do not contribute noticeably into the long term averages.

Figure 5 shows a day time noise map based on long term indications of the stations and noise impact modelling from train and tram operations. It does not include the contribution from air and road corridors. Since there is a significantly smaller number of train and tram movements over the night time periods, SPLs averaged over night time are a lot less than the day time estimates. Transport noise is still high during weekends and public holydays and demonstrate a similar pattern throughout the day time periods.

The Adelaide airport is located close to the West of the CBD, but the main air corridors do not cross the CBD area. There is a small section in the North Adelaide region which intersects the air corridors. Rare flights of light airplanes close to the CBD do not contribute significantly into the measured levels.

Road traffic is the major noise contributor in the CBD. Most heavy vehicles go around the city via the city ring roads, however many bus routes start and end in the CBD, which presumes that the number of bus movements in the city is especially high during day time. Many events characterised by high noise levels (sometimes exceeding L_{Amax} of 100 dB(A) at the monitoring locations) are due to vehicles accelerating along the roads. The noise impact from major roads is localised to the adjacent areas since buildings provide effective screening from noise generated by vehicles.

Although road traffic noise may be the highest contributing noise, overall noise levels are not seen to increase significantly if average daily traffic volumes get higher. If the average daily traffic is increased throughout the city by 10 %, noise levels throughout the city is only expected to increase less than half a dB. The noise in areas that are already predominantly affected by road noise, will not change unless seen to have a significantly large increase in road traffic volumes.

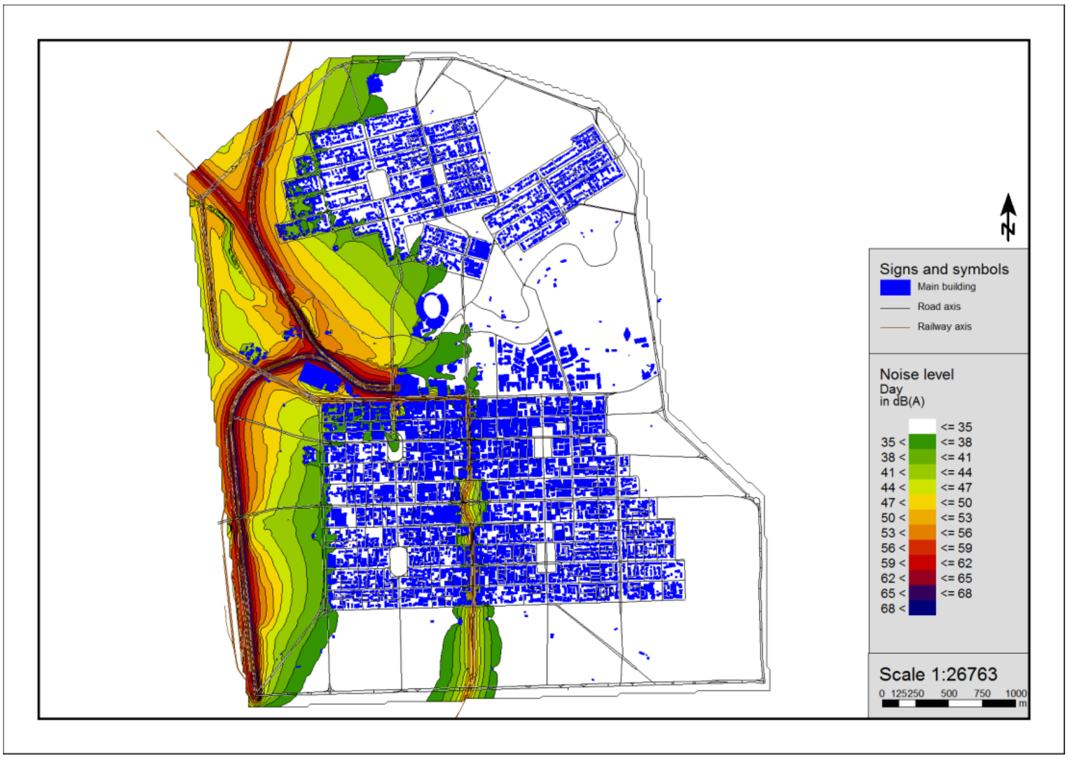


Figure 5: Day time noise levels from train and tram corridors.

4.2 Entertainment noise

Adelaide enjoys a substantial number of festivals, entertainment and sport events such as the super car race Clipsal 500 and the Tour Down Under. The city council encourages organisation of public events in certain open areas such as Victoria Square and Rymill Park in the eastern part of the CBD.

As these events normally take place over both day and night time periods, a combined average is used to represent the noise levels in Figure 6. The main issue with using a 24 hour average is that it may underestimate the actual contribution of the noise levels during the event period by approximately 2-3 dB. This value is based on the comparison with the monitoring data collected for a number of entertainment events.

Analysis of the long term data show that noise associated with entertainment activities is well localised both in time and geographically (refer to Figure 6). For example, Victoria square hosts events associated with Tour Down Under and the Fringe Festival. In Figure 6, an example showing major Fringe events is modelled as area sources based on the data collected over the monitoring period. The impact does not extend far beyond the entertainment areas (Figure 6) and only affects residents of nearby hotels or commercial buildings. The SPL magnitudes acquired during the events are marginally higher in comparison with the long term averages for the affected area. Similar conclusions can be derived for the designated entertainment areas at East Terrace.

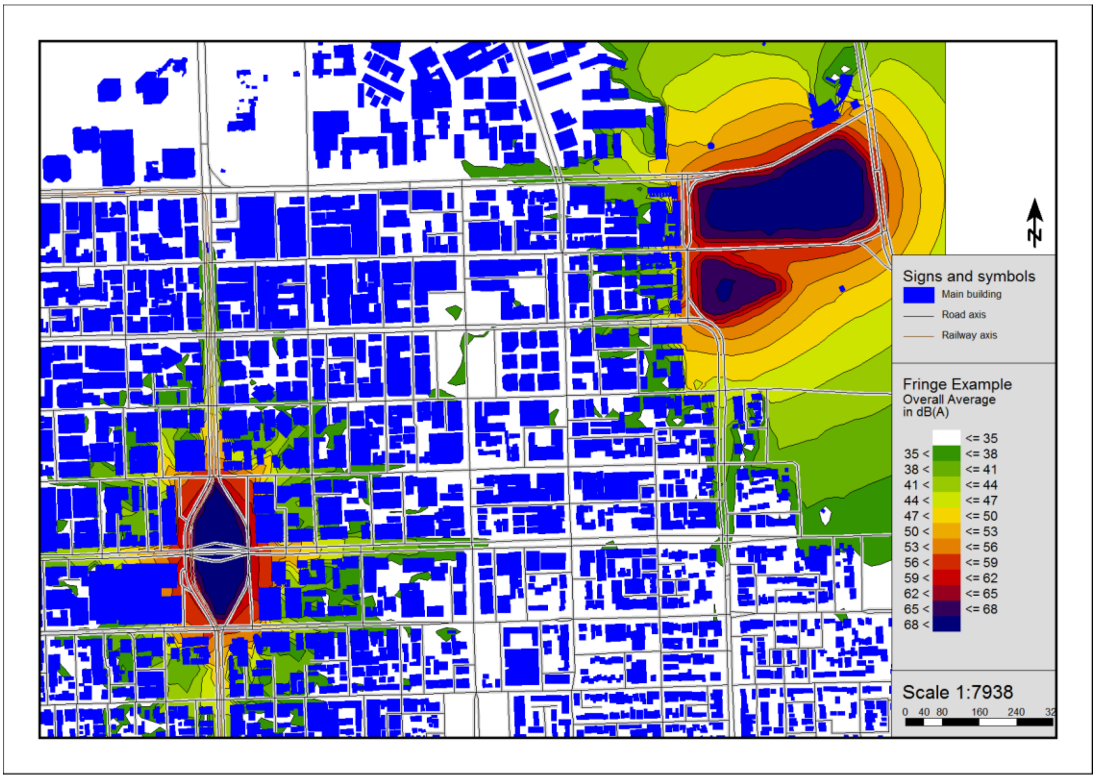


Figure 6: An entertainment noise contribution example in the Adelaide CBD for major Fringe Festival events

5. ASSESSING POPULATION NOISE EXPOSURE

5.1 Current recommendations and methods

The majority of environmental policies and other regulatory documents incorporate certain principles which establish noise limits applicable to individual noise sources. However, meeting the requirement for a particular noise source does not necessarily mean that the amenity in the area corresponds to resident's expectations or health recommendations. The cumulative impact from industrial sources, traffic and local businesses may be significantly higher than the levels recommended for residential or mixed use zones. Moreover, the assessment of noise from different sources may be based on different acoustic descriptors and methodologies. Therefore, a cumulative noise impact based on a single acoustic descriptor gives a better representation regarding the possible adverse effects from noise.

European documents on noise have recommended to use day-evening-night A-weighted SPL for general purposes and assessment of a long term impact. The interim night time goal for Europe is to achieve 55 dB(A) (night) recognising that the ultimate goal of 40 dB(A) (World Health Organization, 2009) can hardly be considered practicable at the moment (refer to Figure 2b). Areas such as the South Eastern part of the Adelaide CBD, which is dominantly residential with hotels and small business buildings, meets the strict noise recommendations. Traffic volumes for South Terrace are relatively small when compared to other arterial roads within the CBD and the city parklands separate this area from the outer ring roads. Other zones of the city with residential infill typically presume that residential buildings should be acoustically treated to reduce internal noise levels down to acceptable limits.

It is obvious that in many cases it is difficult to expect noise levels close to conservative health limits. Urban noise should be assessed against other reasonable limits that are expected in an urban environment during day time hours while night time hours should have outdoor levels low enough to prevent sleep disturbance in an average household.

5.2 Economic and social rationales

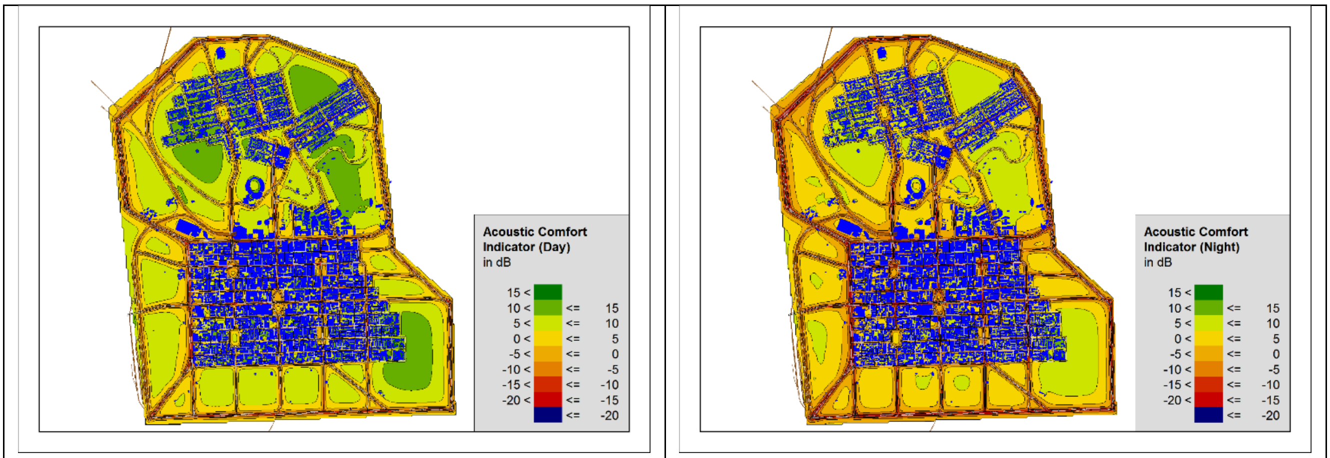
As it was noted above, cumulative noise levels in an urban environment are typically affected by multiple noise sources simultaneously and it is difficult to expect that these levels will meet limits applicable to individual noise sources. The idea of acoustic comfort is similar to that of soundscape design. People expect that noise impact will be higher in some areas such as busy central districts.

We suggest to define acoustic comfort as the difference between the expected comfortable level ($L_{Aeq,R}$) of noise in a particular area and the actual long term estimates:

$$\gamma = L_{Aeq,R} - L_{Aeq} \quad (1)$$

The acoustic comfort parameter can be considered separately for different periods of a day. Distribution of γ shows areas with highest and lowest comfort rather than overall noise. Negative numbers mean that the acoustic amenity in the area is below expectations.

Figure 7 shows the Acoustic comfort parameter of the Adelaide CBD. The $L_{Aeq,R}$ parameter used for day and night time comparison were 65 dB(A) and 55 dB(A) respectively. As expected, areas within North Adelaide that are not next to major transport hubs such as O'Connell Street and Jeffcott Street show much higher acoustic comfort when compared to the rest of the CBD. Areas to the south and south east of the CBD also show zones with much higher levels of acoustic comfort.



(a) (b)

Figure 7: Day (a) and night (b) time Acoustic Comfort Parameter values within the Adelaide CBD

One of the population exposure parameters can be derived on the basis of the acoustic comfort indicator:

$$K_p = (N_d / N_{Tot}) * 100\%, \quad (2)$$

where N_d is the number of residents living in zones of the acoustic discomfort ($\gamma<0$) and N_{Tot} is the total number of residents in the area. The estimates can be calculated for day and night time or other time periods. Accepting the 65 dB(A) level as a benchmark for day time acoustic comfort (acceptable limit for frequent communications in the CBD), we can present a map with zones with sufficient levels of acoustic amenity and with negative γ values where improvements should be considered (Figure 7). The approximate percentage of residents living in zones of discomfort is 34%. It is likely that the number of people actually affected by the higher noise levels is greater since the number of visitors and people working in the CBD is generally greater than the number of permanent city residents. The night time noise level estimates are a more accurate representation in terms of the population exposure. The Night Time Noise Guidelines for Europe established the 1st interim goal of 55 dB(A) (outdoors). The modelling data shows that approximately 51 % of the Adelaide CBD population are exposed to higher levels than this threshold. The population data of the Adelaide CBD were taken from relevant statistics and information sources linked from the Adelaide City Council website.

Similar to the K_p indicator, we can characterise how comfortable a particular area is from an acoustical perspective using the area acoustic comfort (K_s) parameter:

$$K_S = (S_d / S_{Tot}) * 100\%, \quad (3)$$

where S_d is an area where the acoustic comfort parameter is negative and S_{Tot} is the total area. It can also be assessed separately for different periods of a day. Estimates of the area acoustic comfort parameter for day and night time are

38.6 % and 55.5 % respectively. The percentages assess only building areas and do not include the parklands. It was expected that the area with the negative acoustical amenity would be lower during night time hours. The opposite result can be explained by the fact that a reduction in volumes of traffic, which is the major source of noise in the CBD in the long term is balanced out by the expectation of greater amenity during night time hours.

5.3 Population forecast

With the constant growth of the population in the Adelaide CBD, it is expected that the number of people exposed to the higher noise levels will increase as well. It is expected that the population in the Adelaide CBD will increase by approximately 62 % by the year 2036 (Adelaide City Council, 2016). With these statistics we can estimate the percentage of the population exposure to high noise levels (using Formula 2) if the noise environment does not change significantly in comparison with the current situation. The calculated magnitudes are likely to be underestimating the percentage of affected population. This is because the growth of the population could also lead to an increase in the overall noise levels within the city. It is difficult to make an accurate long term forecast of future noise levels since an increase in the number of people and vehicle movements in the CBD may be compensated by a greater percentage of quiet electrical and hybrid cars.

Table 1: Population exposure estimates K_p

Year	Population Estimates	Population Exposure (%)	
		Day	Night
2016	23507	34.2	50.9
2026	31904	36.9	54.5
2036	38124	38.1	56.2

Table 1 shows the population numbers estimated for the years 2016, 2026, and 2036 and the percentage of the population expected to be exposed to the higher noise levels if the noise environment does not noticeably change. With the Adelaide CBD becoming an area with a higher population density, not only are more people expected to get exposed to higher noise levels but a higher percentage of the overall population will be exposed as well. This is mostly because more residents are expected to move into the northern parts of the CBD with more high density residential developments planned; while areas such as North Adelaide are not expected to attract significantly more residents than it already has.

Modelling of noise in the CBD under the assumption that the traffic volume will double in the CBD by year 2036 brings noticeable changes into the estimates in Table 1. The increase in the population exposure by year 2036 could be up to 52.3 % for day time and 62.9 % for night periods. There is a noticeably higher increase during the day time period from 38.1% to 52.3 % when compared to the night time period (56.2% to 62.2%). It is expected that this effect may be less significant in reality due to the projected use of quieter cars or the possible increase in public transport utilisation by the population, leading to a smaller increase in the traffic volume.

6. CONCLUSIONS

A long term noise monitoring project was carried out in the Adelaide CBD. Analysis of the data and strategic noise maps show that the contribution from traffic noise dominates the acoustic environment within the city. Some of the city areas with relatively low traffic flow are suitable for residential developments and others require acoustic treatment of the buildings to be acceptable for residential use with limited outdoor activities.

Entertainment events organised within central city areas and eastern parklands do not cause a significant increase in noise impact. Noise from these events are well localised and mostly affect the closest areas for the limited duration of the event.

Estimating the cumulative noise impact in the area would be considered as the better characteristic to determining the general amenity of an area. It is suggested to compare noise levels with limits in particular zones based on the expected acoustic amenity. A few descriptors were suggested to evaluate the acoustic comfort in an area by taking into account population exposure rationales. The city zones that are characterised by a relatively high population density are generally exposed to higher noise levels. These hot spots should be targeted for acoustic treatments or other measures to reduce the population noise exposure. There is also an economic incentive to consider noise mitigation measures in areas with a higher number of residents.

Additional acoustic indicators represent supplementary information to facilitate planning and noise management decisions in urban areas based on the expected acoustic amenity conformable with the character and use of the area. With the expected increase in population within the Adelaide CBD, developers and planners should have these statistics available to them to allow for planning of noise mitigation solutions in new dwellings or housing planned to be built.

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