ACOUSTICS 2017 PERTH
SOUND, SCIENCE AND SOCIETY

Acoustic comfort in a residential apartment subjected to noise from nearby commercial kitchen refrigeration compressor

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ABSTRACT

With the urban trends towards higher density living and “mixed-use” developments, commercial premises are increasingly being located in close proximity to residential dwellings. Restaurants, cafeteria, bar & bistro and 24-hour gymnasiums below the residential apartments are some common examples of amenities in a mixed-use development that are often a source of noise annoyance. This paper investigates one such scenario where a commercial kitchen is located below a retirement living residential apartment. Sleep disturbance and noise annoyance were key concerns for the resident, even though the measured indoor noise level within the dwelling achieved the acoustic design criteria. Analysis of the measured indoor noise levels and recorded audio showed that a low frequency noise source was cycling on and off periodically every 8 to 10-minutes. This noise source was generating noise levels at least 10 dB higher at 100 Hz than the residual noise in the apartment, and was considered to be the likely source of noise annoyance and sleep disturbance. The noise was traced to a nearby cool room refrigeration compressor associated with the commercial kitchen below. This paper discusses the investigation undertaken and the noise control measures that were implemented.

1 INTRODUCTION

Mixed land-use planning is one of the core elements of the compact city design concept which has widely been recognised as an important mechanism in promoting urban sustainability, urban vitality, efficient use of urban utilities and social cohesion (Foord 2010). “Mixed-use” buildings have emerged as a key design paradigm (Horsfield 2015) in recent years. Mixed-use developments offer the community with a variety of options for entertainment and social gathering. However, a balance is required between activating spaces and ensuring the community benefits of a range of mixed-use experiences (Australian Capital Territory Government 2016). The close proximity of neighbours, shared built features and the services available in mixed development buildings implies a greater degree of shared responsibility and decision-making amongst owners, tenants and property managers (Easthope and Judd 2010). It is therefore important that the design of mixed-use developments ensures that “comfort” within the private space is not compromised by other “amenities” (restaurants, cafeteria, bar & bistro, gymnasium, etc) within or around the development. Such amenities often become a source of noise concern for the residents living in apartments above, leaving the residents with negative perception regarding neighbourhood satisfaction (Wheatley 2014).

This paper investigates one such scenario where a commercial kitchen was located below a retirement living residential apartment. Sleep disturbance and noise annoyance were key concerns for the resident.

2 BACKGROUND OF THE STUDY

The resident of an apartment on the first-floor level of a retirement complex had concerns about a source of noise external to the apartment which occurred during the night time. The subject apartment was located above a commercial kitchen associated with the complex, and it was thought that an item of kitchen plant or equipment may be the source of annoyance. Various items of mechanical plant and equipment were associated with the commercial kitchen below, however, preliminary investigations suggested that noise associated with the refrigerant compressor for the cool room may be the source of annoyance.

3 INVESTIGATION APPROACH AND FIELD MEASUREMENTS

To investigate the source of noise annoyance within the bedroom of the subject apartment, a series of noise measurements were performed as described below:

3.1 Noise Measurements in the Bedroom of Subject Apartment

Continuous unattended noise measurements were carried out over a two-day period in the bedroom of the subject apartment. In addition to measuring the noise levels, the sound level meter was configured to record the ambient sound for the entire period of the measurement, to enable the noises present in the bedroom during the measurement period to be played back later for analysis. There were no occupants in the apartment during the period of noise measurement and therefore the measurement results were not influenced by any activity within the apartment.

3.2 Noise Measurement on the Balcony of Subject Apartment

Unattended simultaneous (in parallel with the bedroom measurement) noise measurements were also carried out outside on the balcony of the subject apartment. This was to assist in determining if the observed noise was due to a a source of noise outside the apartment, or if the noise was being transmitted directly from elsewhere within the building.

3.3 Noise Measurement at Other Locations

Attended short duration noise measurements were also carried out at other locations as follows to assist in identifying the source of the noise.

- Kitchen (Noise from Range Hood and Fridge)
- Corridor at first floor level (with and without kitchen exhaust hood operating)
- Subject apartment (in Bed and Living with kitchen exhaust hood operating)
- Compressor room (inside the room and just outside the door).

4 ANALYSIS OF THE MEASURED NOISE DATA

4.1 Analysis of the Measured Indoor (Bedroom) and Outdoor (Balcony) Noise Data

Noise data from simultaneous measurements within the Bedroom and on the Balcony of the subject apartment are presented in Figure 1 below. It can be observed from Figure 1 that indoor noise levels within the bedroom are below 30 dB(A) throughout day and night. This confirmed that the measured indoor noise levels met the design indoor noise criteria that had been adopted based on AS 2107:2000 (Standards Australia 2000). It is also observed from Figure 1 that outdoor measured noise levels (at Balcony) at night (10pm – 7am) are generally below 40 dB(A) and did not show any significant correlation with variations in door noise level. It is noted that the compressor serving the cool room in the kitchen was operating normally during this period of time.

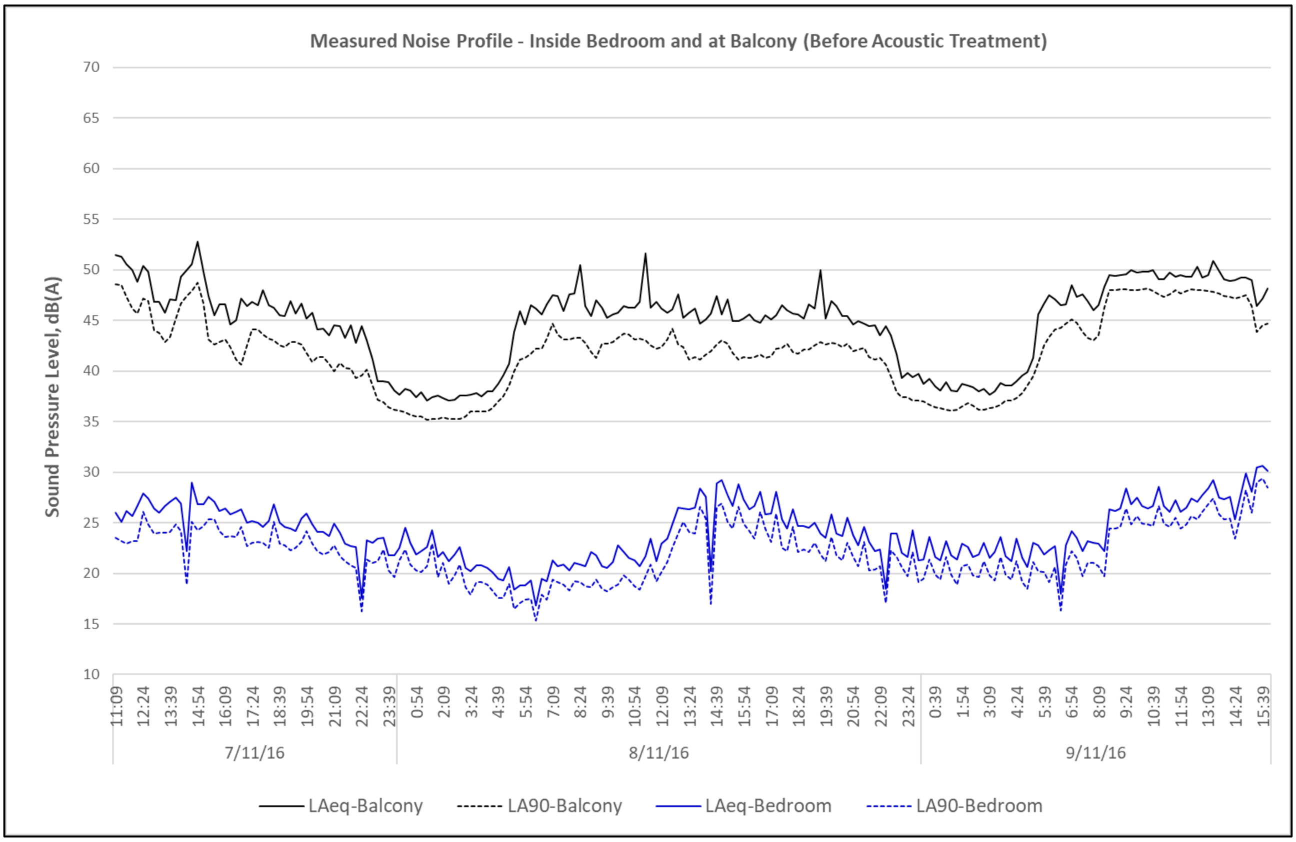

Figure 1 : Measured noise levels (L_{Aeq}) at bedroom and at balcony of the subject apartment

4.2 Higher Resolution Analysis of the Measured Indoor (Bedroom) Noise Data

Measured indoor (bedroom) noise data were further analysed between 12 am and 6 am during the measurement period with a finer time-resolution. Periodic fluctuations in ambient noise levels were clearly observed with this analysis, as shown in Figure 2. This characteristic indicated the was noise from mechanical equipment that cycles on and off, such as a refrigeration compressor. The spikes in the noise profile are indicative of periods when the plant is “switched on” while the lulls between the spikes represent the general background level when the plant is “switched off”.

This “switch on” and “switch off” mode is found to occur in every 8 to 10 minutes which correlated with typical operation of the cool room compressor. Figure 2 shows that there is a clear 10 dB to 12 dB rise in noise level within the bedroom between these “switch on” and “switch off” modes. It is also noted that the general background noise level between the spikes is particularly low (approximately 15 dB(A) or less), which means that it may be very difficult to reduce the plant noise to a point where it is no longer audible.

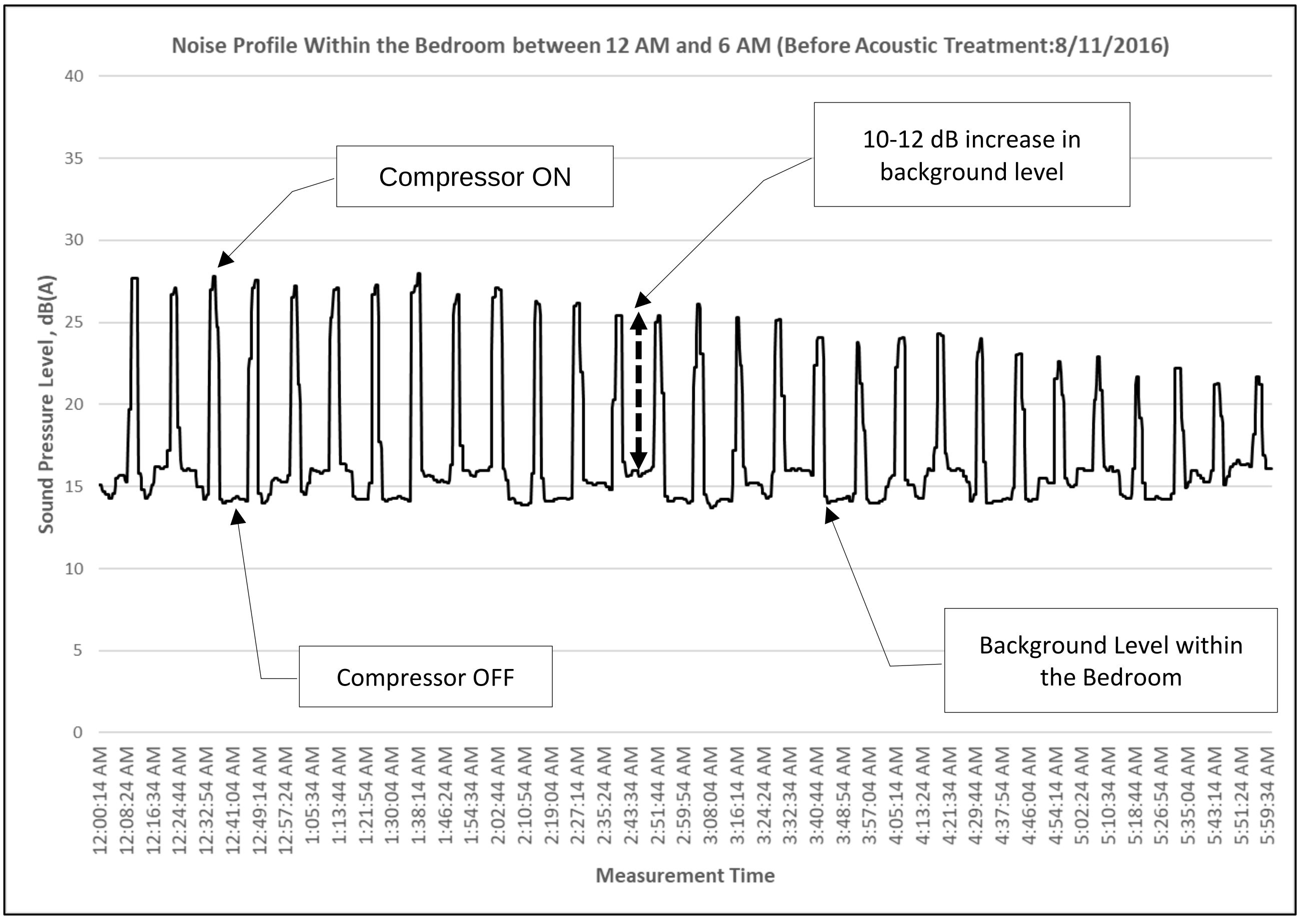

Figure 2 : Noise profile illustrated between midnight 12am and morning 6am (8th November 2016)

The above analysis demonstrated that noise due to the kitchen refrigeration compressor was very likely to be the source of noise annoyance and sleep disturbance during the night.

4.3 Analysis of the Frequency Spectrum Noise Data

Frequency analysis of attended measurements that were performed close the cool room compressor, and the measurements in the bedroom of the subject apartment reveals a strong low frequency noise component at 100 Hz in both locations, adding further support that the compressor was the source of the noise being observed in the bedroom. The frequency spectra measured in the bedroom and close to the compressor are presented in Figure 3.

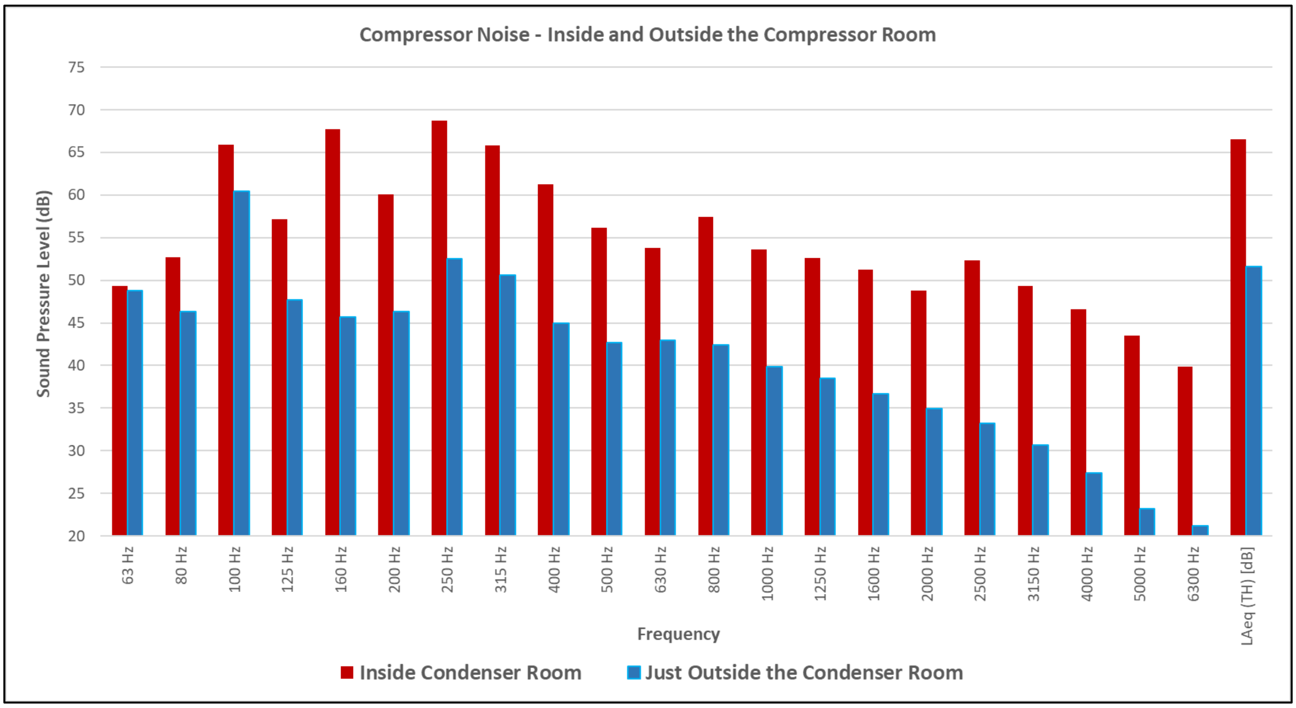

Figure 3 : Frequency spectrum showing dominant compressor noise at 100 Hz (outside the room)

4.4 Analysis of the Recorded Sounds in the Bedroom

Sounds within the bedroom were recorded during the entire period of the measurements. The sounds recorded during selected parts of the measurement period were played back to ascertain the nature of noise within the bedroom, especially during the period from 11pm to 5am. Low frequency noise, likely to be due to the compressor was often able to be heard in the recorded sound files. Spectrum analysis of the recorded sound files at the times when the sound could be heard showed that the dominant frequency of the noise was approximately 100 Hz, which coincides with the findings discussed above.

5 RECOMMENDED NOISE CONTROL MEASURES

The following recommendations were made for control of low frequency noise from the refrigerant compressor:

- It was recommended to relocate the compressor further away from the apartment in an enclosed non-noise sensitive area. At the time of the investigations the compressor was located in the car park on the ground floor level, not far below the balcony of the subject apartment on the first-floor level. Based on the site visit, a recommendation was made to relocate the compressor further into the enclosed carpark area.
- As shown in Figure 4, the enclosure containing the compressor is rigidly mounted from the soffit of the car park.. It was recommended to resiliently mount the enclosure using appropriate vibration isolation hangers to reduce the transmission of structure-borne vibration and noise.
- As shown in Figure 5, the compressor was enclosed with flexible noise barriers and there were openings all around which did not effectively contain noise within the enclosure. It was therefore recommended that the compressor enclosure should be fully enclosed with dense rigid panels internally lined on all sides with acoustic insulation.
- In addition to the above recommendations, it was also noted that the background noise levels in the apartment were extremely low, and this was considered to be resulting in the noise from the compressor being more easily heard. It was suggested that a white noise masking system could potentially be used in the apartment to increase background noise levels slightly. This would have the effect of masking the intrusive noise from the compressor, and reducing its audibility. A properly configured white noise system would not result in any reduction in amenity in the apartment.

Figure 4 : Figure Illustrating Compressor Enclosure Mounting on the Ceiling Slab

Figure 5 : Figure Illustrating Compressor Enclosure

6 POST TREATMENT (NOISE CONTROL) NOISE ASSESSMENT

As recommended, the kitchen cool room refrigeration compressor was relocated to a position further into the covered car park of the property away from the subject apartment. No other acoustic treatments were applied.

To examine the effectiveness of the implemented noise control measures, the unattended noise measurements were repeated over a two-day period following the remedial works.

A comparison between the noise profiles measured in the bedroom before and after implementation of the noise control measures is shown in Figure 6.

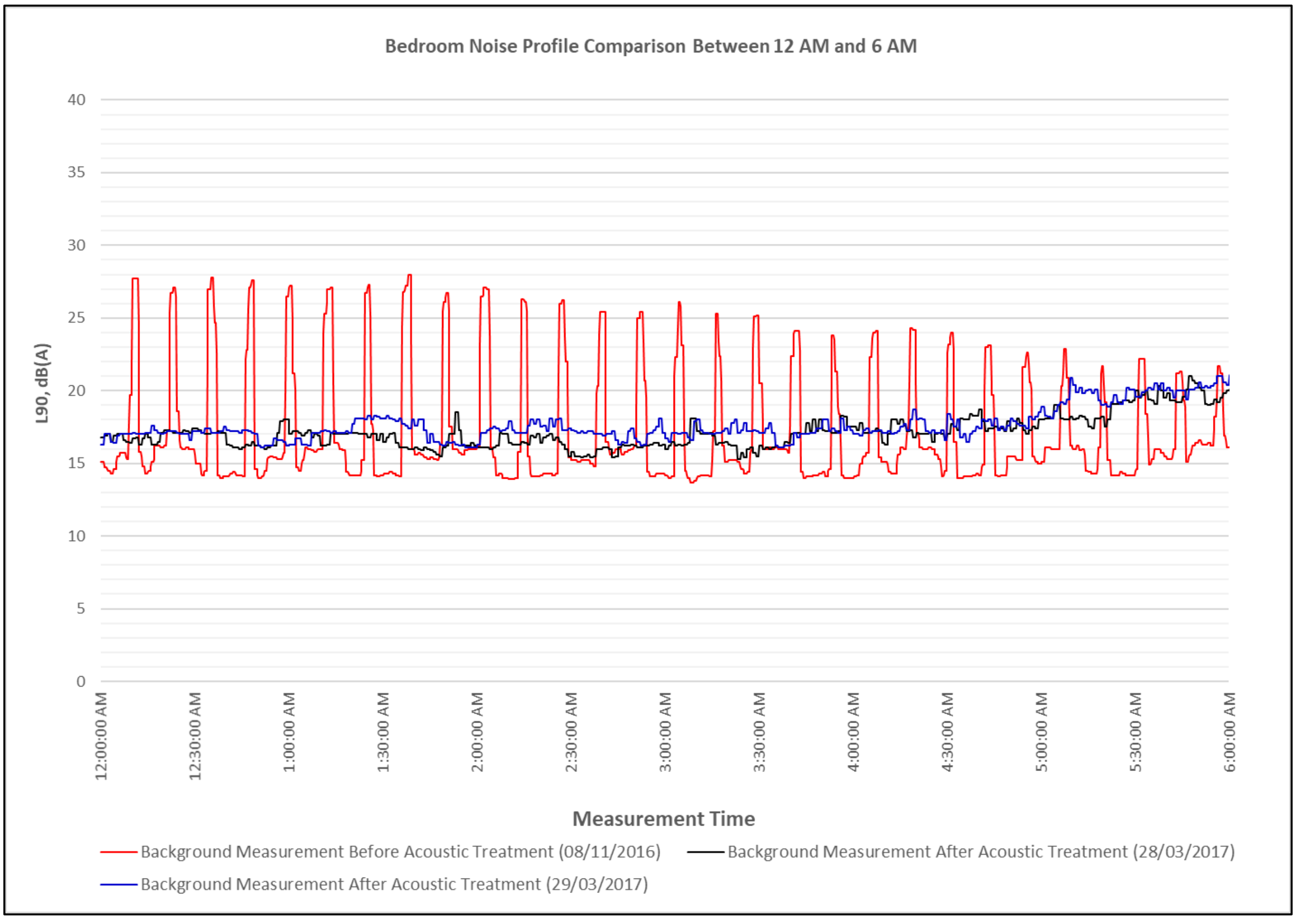

Figure 6 : Bedroom Noise Profile Comparison Before and After Control Measures

From review of the measured indoor noise levels in the bedroom on both nights, it is evident that the ambient noise levels within the room no longer show the periodic characteristic previously seen before implementation of noise control measures. This confirmed that the compressor was correctly identified as the source of the elevated noise within the subject apartment, and that relocation of the unit was effective in reducing this noise within the bedroom of the apartment.

7 FUTURE CONSIDERATIONS FOR MIXED-USE BUILDING DESIGN

The investigation discussed in this paper illustrates the importance of considering temporal and spectral characteristics of potential noise sources when developing noise control strategies in mixed-use development. It also illustrates the importance of considering whether sufficient background noise will be present in a space to mask extraneous noises to prevent their audible emergence.

Building standards such as AS/NZS 2107 specify absolute criteria in terms of overall indoor sound levels, as they can be easily predicted from equipment manufacturers data and acoustic calculations. However, the use of only overall levels potentially underestimates the true impact and annoyance of the noise source. As a result, the overall design sound levels might be achieved without actually addressing the components of the source characteristics that are most likely to cause annoyance. Care needs to be taken by designers to consider these other aspects, even for predicted low level sources.

However, unless mandated by building standards and criteria to consider such factors, it is likely that issues similar to the example highlighted in this report will continue to occur, as builders and their consultants strive to achieve the lowest construction costs that “meet the standards”.

Whilst standards such as AS/NZS 2107 provide some guidance, it is considered that increased emphasis on these matters would be prudent, perhaps such as including some form guidance for emergence of sources above background. However, in better addressing these matters in a Standard, a balance would need to be achieved between criteria that can be held to test, and the flexibility to cover a wide range of situations without creating onerous burdens on designers and builders.

8 CONCLUSION

Living in a mixed-use development in an urban area benefits residents in a variety of way including entertainment opportunities, platforms for social gathering and proximity to different services required in day to day life. However, by putting all these facilities together, the designers bring the noise sources close to the living environment (dwellings). Acoustic comfort can then be compromised in living spaces, resulting in noise annoyance and sleep disturbance. It is suggested that designers need to consider not only the overall sound levels prescribed by design standards, but also the true anticipated background sound levels in the finished spaces and the spectral and temporal characteristics of the sources which could potentially impact on those spaces.

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