# Annoyance from the sudden onset of noise

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## ABSTRACT
In 2014 the Australian Rail Track Corporation (ARTC) completed the Scone Reconfiguration Project. The reconfiguration project included the removal and realignment of existing rail infrastructure and the construction and installation of new turnouts. The reconfiguration allows trains to travel through the Scone township at an operational speed of 50 km/h rather than 25 km/h. The increased operational speed increased wayside noise levels, resulting in the recommendation of reasonable and feasible noise mitigation. A combination of noise barriers and architectural treatment was recommended. One noise barrier, 4.2 metres high, extends partially across the north side of St Aubins Street West (on the Down side of the tracks). A warehouse is located on the Up side of the St Aubins Street, resulting in a gap in the noise wall of approximately 17 metres. The resulting noise environment comprises noise from trains that are well shielded and then suddenly emerge from the noise barrier creating a fast and appreciable onset of noise. The majority of movements are freight at this location. While the rail line has existed at this location as long as the township, long-time residents have begun complaining as a result of the new noise wall. It has been claimed that the new noise wall has created an annoyance issue. The exhaust noise is the dominant noise source contributing to the reported annoyance. This paper explores the local noise environment, establishes a means to determine annoyance which relates to existing noise criteria and considers other psychological factors which can contribute to the annoyance associated with the environment. Findings are provided which include recommendations for determining the likelihood of annoyance as a result of the onset of noise and recommendations to mitigate against the occurrence of these events.

## 1. INTRODUCTION
In March 2014 an environmental noise assessment was completed for the Scone Reconfiguration Project by another consultant. The reconfiguration project included the removal and realignment of existing rail infrastructure and the construction and installation of new turnouts. The reconfiguration allows trains to travel through the Scone township at an operational speed of 50 km/h rather than 25 km/h.

The increased operational speed would increase wayside noise levels, resulting in the recommendation of reasonable and feasible noise mitigation. A combination of noise barriers and architectural treatment was recommended. One noise barrier, 4.2 metres high, extends partially across the north side of St Aubins Street West (on the Down side of the tracks). Home Hardware is located on the southern side of the St Aubins Street West, about 88 metres south of the noise wall. Home Hardware comprises a large industrial shed which provides shielding to residential properties to the south. A 2 metre high fence is located between the railway line and Home Hardware, between this fence and the noise wall there is a gap, approximately 17 metres long.

The residents located at St Aubins Street, West have complained about a perceived noise issue from the noise wall and passing trains. Annoyance is caused when the train quickly appears from behind the barrier, creating almost a startle effect. A canyoning noise issue has also been reported where train noise is reflected between sheds up the rail line and then propagates out of the gap onto St Aubins Street West.

The purpose of the project was firstly to determine how annoyance can be identified from the sudden onset of noise and what other factors can contribute to perceived annoyance at the site location. Measurements were then undertaken at St Aubins Street West to determine if annoyance is likely to occur when trains pass the measurement site.

## 2. PREVIOUS WORK
Many studies have been conducted to establish relationships between annoyance levels and noise exposure levels. Conventional methods of assessing human annoyance due to noise, such as that developed by Schultz (Schultz, 1978), are based on studies carried out on the human response to highway, railroad and commercial aircraft noise sources. Schultz developed a relationship between community noise exposure (expressed as a day-night level, $L_{DN}$) and the prevalence of annoyance (expressed as percentage highly annoyed, %HA). Throughout the

years research has been undertaken to improve the original Schultz relationships, by taking into account more survey data points and more sophisticated models (Fidell et al, 1991 and Miedema & Oudshoorn, 2001). Miedema and Oudshoorn also improved the relationship by separately analysing different modes of transport. Their relationships for railway noise, which is based on ten data sets, are given below:

$$\%LA = -3.343\times10^{-4}(L_{DN}-32)^3 + 4.918\times10^{-2}(L_{DN}-32)^2 + 0.175(L_{DN}-32) \quad (1)$$

$$\%A = 4.552\times10^{-4}(L_{DN}-37)^3 + 9.400\times10^{-3}(L_{DN}-37)^2 + 0.212(L_{DN}-37) \quad (2)$$

$$\%HA = 7.158\times10^{-4}(L_{DN}-42)^3 - 7.774\times10^{-3}(L_{DN}-42)^2 + 0.163(L_{DN}-42) \quad (3)$$

In these relationships %LA, %A and %HA are the percentage of persons who are “(at least) a little annoyed”, “annoyed” and “highly annoyed” respectively, $L_{DN}$ is the day-night level which is defined in terms of the $L_{Aeq}$ during daytime (7am-10pm) and night-time (10pm-7am) and applies a 10 dB(A) penalty to noise in the night.

This paper particularly considers annoyance due to a sudden onset of noise. Stusnick et al (Stusnick et al, 1993) investigated the annoyance to noise from low-altitude military training route flight operations. They found that onset rates (the change in noise over time at the initial increase in noise) faster than 15 dB/second caused annoyance beyond what would be expected from the corresponding sound exposure level (SEL). An adjustment factor which is added to the highly annoyed percentage, effectively increasing the percentage of the population which are likely to be annoyed by the noise, based on the onset rate was determined.

The best fit to the data was found to be an onset rate adjustment to $L_{DN}$, given below:

$$ADJ = \begin{cases} 0, & for\ OR < 15 \\ 11.0log_{10}(OR) - 12.9, & for\ 15 \le OR \le 150 \\ 11, & for\ OR > 150 \end{cases} \quad (4)$$

In addition to direct acoustic factors such as average noise levels and onset rate, indirect non-acoustic factors have an impact on community response or annoyance. Plotkin et al (Plotkin et al, 2011) compiled a list of non-acoustic factors based on six reports. The factors are categorised as either first or second order and are listed in Table 1. In relation to this project relevant first order non-acoustic factors might be *preventability* and *change in noise environment*.

Table 1: Non-acoustical factors affecting community annoyance

| First order | Second Order |
|---|---|
| Fear of noise source | Avoidability |
| Preventability | Choice in compensation (societal) |
| Sensitivity to noise | Expectations regarding future of source |
| Change in noise environment | Information (accessibility and transparency) |
| Attitude towards source | Predictability of noise situation |
| Choice in insulation | Procedural fairness |
| Choice in compensation (personal) | Duration of residency near infrastructure source |
| Influence, voice | Fear related to source noise |
| Perceived control | Home ownership (fear of devaluation) |
| Recognition of concern | Use of infrastructure |
| Trust | Benefits from infrastructure (personal, society) |
| Past experience with source | Cross cultural differences |

| | |
|---|---|
| Individual sensitivity to noise | Country of origin |
| Perceived predictability | Media coverage and heightened awareness to source |
| Income | Social status |
| Age | Age (above 55) |
| Understanding | Awareness of negative consequences (health, learning) |
| General attitudes | Children |
| Personal benefits | Education |
| Compensation | Accessibility to information |
| Home ownership | |

In addition to the above factors Babisch (Babisch, 2012) determined exposure modifiers of the relationship of road transportation noise with noise annoyance based on a survey of 4,861 people aged between 45 and 70 years. Below are two of the factors which they listed as having a significant association with the annoyance rating:

- Subjects whose living room or bedroom was shielded by obstacles from the street were less annoyed by road traffic noise than those without shielding for the same $L_{DN}$.
- Subjects who could see the street from their living room or bedroom were more annoyed by road traffic noise than those who could not see the street for the same $L_{DN}$.

### 2.1 The relationship between the Rail Infrastructure Noise Guideline and annoyance

The Rail Infrastructure Noise Guideline (RING) provides rail noise assessment criteria for heavy and light rail infrastructure. The RING establishes a series of trigger levels for assessment of rail projects. Noise from a rail project above any one of these trigger levels results in the need to consider feasible and reasonable noise mitigation measures.

Provided below in Table 2 is a summary of the criteria for residential receivers.

Table 2 - Heavy Rail Airborne Noise Trigger Levels - Residential Receivers

| Type of Development | Noise Trigger Levels (External) | |
|---|---|---|
| | Day (7am to 10pm) | Night (10pm to 8am) |
| New rail line development | 60 dB(A) ($L_{Aeq(15\text{-hour})}$)<br>or<br>80 $L_{AFmax}$ | 55 dB(A) ($L_{Aeq(9\text{-hour})}$)<br>or<br>80 $L_{AFmax}$ |
| Redeveloped rail line | Increases $L_{Aeq(period)}$ rail noise by ≥ 2 dB(A) or $L_{Amax}$ rail noise by ≥ 3 dB(A) and<br>65 dB(A) ($L_{Aeq(15\text{-hour})}$)<br>or<br>85 $L_{AFmax}$ | 60 dB(A) ($L_{Aeq(9\text{-hour})}$)<br>or<br>85 $L_{AFmax}$ |

These criteria can be directly related to the highly annoyed calculation discussed above. For a redeveloped railway, the RING noise criteria correlate to approximately 9% of the population being highly annoyed by noise associated with railway respectively. This highly annoyed percentage aligns reasonably well (generally within ±1-2%) consistently with noise criteria used for other modes of transport used in Australia and internationally.

The highly annoyed percentage (%HA) is considered to be a reliable parameter for this study as it relates directly to the existing criteria, provides a good analysis (in terms of percentage) of the likelihood that the event can be considered annoying, and can incorporate the additional annoyance from the sudden onset of noise created from a train passing at high speed from behind a noise barrier.

## 3. NOISE MEASUREMENTS AND ANALYSIS

Attended noise measurements were undertaken at the site to determine the onset rate and determine if this influenced the likelihood for sensitive receivers to be annoyed. It was surmised that the onset rate should be impacted by a 20 log distance relationship, while noise from the train passby would be controlled by a 10 log distance relationship. As such the onset rate should have a larger impact at nearer distances than further distances. To measure the change in onset rate over distance simultaneous noise measurements were undertaken at three different offset distances 11 metres, 20 metres, and 40 metres. Data was recorded as wav files and post processed in Matlab.

The measurements identified that the onset rate for the freight trains coming from the down direction (not from behind the wall) was around 2 dB(A)/sec. The onset rate for the freight trains coming from the up direction (from behind the wall) is notably higher at around 6 dB(A)/sec.

This increase confirms that relatively speaking, a train emerging from a noise wall is more annoying than a train that does not. However it is still significantly lower than the onset rate at which a correction for annoyance has to be made according to equation (4). The OR adjustment equation identified in equation (4) requires the OR to be greater than 15 before an adjustment is calculated. The maximum OR measured was 8.6, well below the threshold of 15. This suggests that the additional annoyance from noise is not created by the sudden onset of noise caused by the termination of the noise wall.

The measurement results were also assessed against the RING criteria and the HA%. The levels were compliant with the RING criteria and achieved a %HA of 8% at the nearest measurement location. These results indicate that the noise wall is compliant with the applicable noise policy, and based on the noise level only would not be more annoying than other locations on the NSW network.

However the guidelines and the %HA formula are designed to provide a very analytical assessment of noise impact, which does consider non-acoustic impacts. Other impacts identified in Table 1 can contribute to the perception of noise impacts, which can increase the final annoyance.

It was noted on site that predominantly due to the limited maximum speed of approximately 50 km/h, this specific location was not considered to be particularly annoying based on the noise level alone. It is worth noting a member of the community could still find the noise event annoying, even if the probability is low. This probability may be increased due to the presence of non-acoustical factors.

A small number of community members came to discuss the purpose of the site work whilst the measurements were being undertaken. While each community member had differing opinions about the noise environment, they all agreed that it was obvious that the noise wall should have been extended during the design.

A short length of noise wall could have been included in the design which bridged the gap between the existing noise wall and the fence at the rear of Home Hardware. It is understood that at the time of the design there was a competing visual amenity requirement. Some residents preferred that a gap be maintained so that the view was not completely blocked which may have influenced the final design.

## 4. CONCLUSIONS

Previous work undertaken in Scone and assumptions based on existing impacts led to an early interpretation of the likely noise problem. The literature review focused on the assumed issue, which was the high noise onset rate. While this assumption proved to be invalid for the site, the literature review was fortunately was broad enough to consider secondary impacts.

Site measurements identified that the onset rate was not a significant issue. The onset rate generated by the trains emerging from the noise wall was greater than trains that do not emerge from behind walls, however the highest level was half the amount required to trigger an annoyance correction according to Stusnick et al (Stusnick, et al, 1993). The use of the formula identified here is considered appropriate, however further work is required to confirm this assumption.

The investigations also identified that annoyance from noise can be heightened from contributing factors. For this project the community considered it very easy to reduce the source of the annoyance, with a large perceived benefit. This contributing factor has increased the apparent annoyance from the source. While these factors cannot always be included in the design, where opportunities exist to reduce annoyance, they should be considered.

While not required, extending the designed noise wall an additional 17 metres is unlikely to have been a significant cost in the scope of the project. Consideration should be given in the design stage of a project to secondary non-acoustic factors that may increase annoyance in nearby noise sensitive communities.

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