Design targets for Child Care Facility in the vicinity of intermittent noise sources

Tom Krikke[1]

[1] Norman Disney & Young, Sydney, Australia

ABSTRACT
Childcare or young education centres are being built in close proximity of intermittent noise sources such as helipads of hospitals, railway lines or non-commercial airports. Due to the nature and occurrence of this type of noise, no current regulations or standards are available to use as design guidelines. Research indicates that, compared to adults, children may be more prone to the adverse effects of noise, due to the lack of ability to control the environment. In addition, they are more susceptible to the impact of noise. Unfortunately, little is known about the impact on babies and young children's health and well being for once a day or once a week noise events. However, high noise levels have been proven to cause sleep disturbance, higher stress levels and learning disadvantages for young children. Based on available guidelines and research, this paper recommends that maximum noise levels are determined as design standards for new child care centres located in close proximity to intermittent noise sources for once a day or once a week events. The paper recommends that internal noise levels should be limited to minimise sleep disturbance and impact on noise induced hearing loss.

1. INTRODUCTION
Childcare or young education centres (for ages 0-6 years) are being built in close proximity of intermittent noise sources such as helipads of hospitals, railway lines or non-commercial airports. Due to the nature and occurrence of this type of noise, no current regulations or standards are available to use as design guidelines.

There appears to be more awareness amongst architectural, educational and acoustic professions about the effects of noise on children, resulting in currently updated acoustic design guidelines for school designers. Unfortunately, these do not address noise levels from intermittent noise sources.

The author has been involved in Childcare centre and student accommodation design with external noise levels up to 110 dB(A) L_{Amax}. However, much higher noise could be experienced in extreme cases with modern military aircraft.

During the author's design involvement it was difficult to establish suitable design criteria, while outweighing children's health on one side, against the clients financial interests on the other side. The closest to an actual design target the author found was "*It is recommended that new schools should not be planned close to existing airports*". However, this does not provide any real design guidance if the client persists to build a childcare centre near an intermittent noise source.

This paper discusses some of the considerations that have to be made in design for child care centres and school accommodation near intermittent noise sources. No new data are presented in this paper. This paper is intended to assemble the scattered evidence and open the debate to setting appropriate (maximum) noise levels for future childcare, school or student residences design near intermittent noise sources, such as military airports, hospitals (with a helipad), or goods rail corridors.

Lastly, recommendations are given for setting appropriate internal criteria.

2. CURRENT REGULATIONS
Current Australian Standards and guidelines do not suitably address acceptable noise limits for intermittent (aircraft) noise applicable to young children and babies. These regulations and guidelines are focused on the impact of (semi-)steady-state noise levels on the health and education of children; while legislation to control intermittent or impulse type noise sources are mainly focused on adults.

World Health Organization (WHO) (Berglund, 1999) recommends that for outdoor playgrounds of a childcare centre, the sound level of the noise from external sources should not exceed 55 dB(A) L_{eq}. This recommendation is consistent with the Association of Australian Acoustic Consultants (AAAC, 2010) guidance for noise emission from road rail and traffic of 55 dB(A) L_{eq} for outdoor play activity areas. However, neither WHO, nor AAAC make mention of intermittent noise sources acceptable limits.

2.1 Australia

2.1.1 Australian Standards

AS/NZS 2107:2000 (Standards Australia, 2000) recommends continuous equivalent noise levels ($L_{Aeq,T}$) for design noise levels for various occupancies. These design noise levels are explicitly stated as steady-state or quasi-steady noise sources. Additionally, the standard notes that it is not intended for the assessment or perception of transient or variable noise sources such as aircraft and railway noise. The standard is however useful in quantifying the relative differences in expectations between sensitive spaces.

Secondly, the Australian Standard for aircraft noise AS 2021:2015 (Standards Australia, 2015) outlines acceptable indoor design noise levels for (commercial) aircraft noise and recommends an indoor design sound level of 50 dB(A) for sleeping areas and 55 dB(A) for 'teaching areas'. The major limitation in applying AS 2021 is that this standard is specifically developed noise from commercial aircraft and buildings in the vicinity commercial airports. Nominated design targets are therefore not necessarily representative for less frequent (but potentially longer event duration) intermittent events, such as military aircraft, helicopter movement or train pass bys.

Lastly, although both of these standards may give rough design guidelines, neither of these standards specifically mention childcare centres.

2.1.2 NSW

NSW Road Noise Policy (EPA (NSW), 1999) states that noise levels of 50 to 55 dB(A) are unlikely to awaken people. Additionally, one or two noise events per night with maximum internal noise levels of 65 to 70 dB(A) may wake people (i.e. not babies), but are not likely to adversely affect health and wellbeing. It should be noted that according to the NSW RNP, there is still insufficient evidence to set criteria for sleep disturbance.

These guidelines discuss the probability of awakenings to an exposed maximum noise level, and cite the work of Bullen (1996), as discussed later in this paper. Their findings indicate that the mean number of awakenings with a noise level of 65 dB(A) L_{max} is approximately 5 percent.

It is noted that these numbers, and the policy, relate to transient road and rail noise sources. Therefore the recommendations outlined in the NSW Road Noise Policy may not be applicable to intermittent noise sources and additionally may not apply for young infants.

2.1.3 VIC

In Victoria, a helipad can be no closer than 500 metres from child care centre that is not associated with the helicopter operation (Department of Planning and Community Development (VIC), 2012); however a childcare centre in a hospital is associated with the helipad. If a childcare centre is located closer, the helipad needs to comply with the Victorian Noise Control Guidelines Additionally; helicopter landing sites intended for emergency use are exempt from the planning scheme requirements.

2.2 UK

The Building Bulletin 93 School design guide (Department for Education and Skills (UK), 2014) provides much information for design of schools and the impact of noise on Children's health. However, specific noise criteria for intermittent noise are not provided. The guideline notes that 60 dB(A) $L_{eq,30min}$ should be regarded as an upper limit for external noise, but up to 70dB(A) may be acceptable but will require considerable facade design.

Similarly, the UK Institute of Acoustics (IOA) and the Association of Noise Consultants (ANC) design guide for schools (IOA, 2015) recommend that for sites where external noise levels are 70 dB(A) or higher, significant acoustic treatments may be required for the building façade performance.

3. CHILD'S WELLBEING RELATING TO NOISE

Unfortunately, little is known about the impact of noisy environments on babies and young children's health and well being; especially for once a day or once a week noise events. However, high noise levels have been linked to cause sleep disturbance, higher stress levels, learning disadvantages and it may even trigger aggressive behaviour (AAP, 1999) for young children.

Nonetheless, research findings suggest that exposure to uncontrollable noise may make children more vulnerable to learned helplessness and typically children may be routinely exposed to more noise than the 24-hour equivalent of 70 dB(A) L_{eq} (Tamburlini, 2002).

3.1 Learning ability

Much research has been undertaken into the effects of noise on children's learning and performance at school and there appears to be a general consensus that noise has a detrimental effect onto the learning and attainments of children (Shield, 2003), with children in the primary school age range appearing to be the most affected by noise. Shield's research indicates that high noise levels appear to have the most effect on high cognitive processing tasks, such as attention, problem solving and memory. From research it is also evident that higher noise levels are detrimental to speech comprehension, particularly for younger children with lower proficiency in the linguistic skills (Wang, 2014).

Unfortunately, one of the major shortfalls of the available research is they are based on "noisy" or "quiet" environments (Fican, 2000) and that the noise level is typically not quantified or are based on (semi-)steady-state noise levels and therefore a suitable design standard cannot be derived from these studies.

Luckily, there are some studies available that quantify noise levels connecting to learning ability. The interference with speech is often linked. High noise levels can have especially detrimental effects on younger children when language and discrimination skills are forming (Maxwell, 2016). Problems arise when the ambient noise is 60 dB(A) or more. Aircraft noise exposure was associated in a linear exposure effect association with reading comprehension. Maxwell et el. estimated that a 5 dB(A) increase in noise was associated with a 2-month impairment in reading age.

It is noted that, as per the above study from Maxwell, studies mainly focus on chronic noise exposure (from both environmental noise and other kinds of classroom noise). As per the above example, most studies are undertaken near public airports, suburban rail and/or road corridors and are therefore based on (semi-)steady state noise sources. For example, a study undertaken by Evans & Maxwell (1997) identified a link between chronic noise exposure from a nearby airport; planes flew over the school on an average of every 6 minutes resulting in noise levels of 90 dB(A) inside classrooms. However, it should be queried if a noise level in the order of 90 dB(A) every 6 minutes would have the same effect as an aircraft flyover of 100dB(A) once every hour. In both cases the class would be disrupted and one could argue that 90 dB(A) every 6 minutes would be more disruptive and could potentially be more harmful. This query was also asked in the FICAN (Fican, 2000) report, but the FICAN noted that funding would be unlikely to be granted to such a research. This appeared to be a correct assumption as the author of this paper was unable to find any research relating to this query based on (primary) school children.

3.2 Noise induced hearing loss

Noise induced hearing loss is caused by high noise exposures and all age groups can be affected. Even though noise induced hearing loss is well recognised in professional settings in adult life, typically little to none attention is given to the potential of noise induced hearing loss of young infants. The health effects of noise include hearing damage from impulse noise at high levels which may damage inner hair cells and from prolonged exposure to loud noise levels. Hearing loss may be transient and is typically permanent. In Australia, a noise exposure level of 85 dB(A) $L_{eq;8hour}$ is the Occupational Health and Safety (OH&S) (NOHSC, 2000) limit. In practice this often results in design noise levels for noisy spaces of no more than 85 dB(A). For spaces where higher noise levels are expected, personal protective equipment (PPE) measures such as the usage of earmuffs should be in place.

The OH&S standard does not differentiate between young and old, and the nominated criterion applies to all ages. Current implemented measures are unpractical and unrealistic to implement for young infants and babies. Additionally, it is unclear how noise levels affect hearing of babies and infants. Young children and babies are typically exposed to relatively noisy environments. As per previously mentioned WHO research (Tamburlini, 2002), noise levels that children are routinely exposed to typically exceed 70dB(A) $L_{eq;24hr}$. Exposure to these types of high noise levels from early childhood might have cumulative effects on hearing impairment in adulthood. Evidence is increasing that early exposure to noise might affect hearing in middle age (Lancet, 2014). Unfortunately, how noise and age interact is a major gap in our current research. However, research suggests that early noise exposure substantially increase the risk of inner ear ageing and related hearing loss (Lancet, 2014).

3.3 Non-auditory health

Non-auditory health effects of noise are still a relatively unclear aspect of high noise levels, for adults, let alone children. Although various research papers link high noise exposures to non-auditory health effects including annoyance, cardiovascular disease and impairment of cognitive performance in children (Lancet, 2014).

Because the non-auditory effects on children and young infants are not sufficiently researched at this stage, these are not further discussed in this paper. However, it is noted that setting a suitable design target should take the potential of the non-auditory impacts into account.

3.4 Sleep awakening

Sleep disturbance is taken to be the most deleterious indirect non-auditory effect of noise exposure, because undisturbed sleep is needed for alertness and performance, quality of life and health (Lancet, 2014).

Even at low noise levels, unwanted noise has the potential to interfere with sleep (Shepherd, 2010).There appears to be a general consensus that a noise level of 45 dB(A) L_{max} is the lower limit to avoid any sleep disturbance for adults as outlined in the World Health Organisation (WHO) guidelines (Berglund, 1999) community noise as follows:

> *If the noise is not continuous, sleep disturbance correlates best with L_{Amax}, and effects have been observed at 45 dB or less.*

Typically, sleep awakening is classified as a percentage increase in chance of awakening relatively to noise levels. Real data for highly intermittent noise sources is not yet available. However, upon review of acceptable hospital criteria, Bullen (1996) provided the following summary of studies with sleep awakening events to maximum noise levels. It is noted that these values are based on transient noise sources, such as rail and traffic noise.

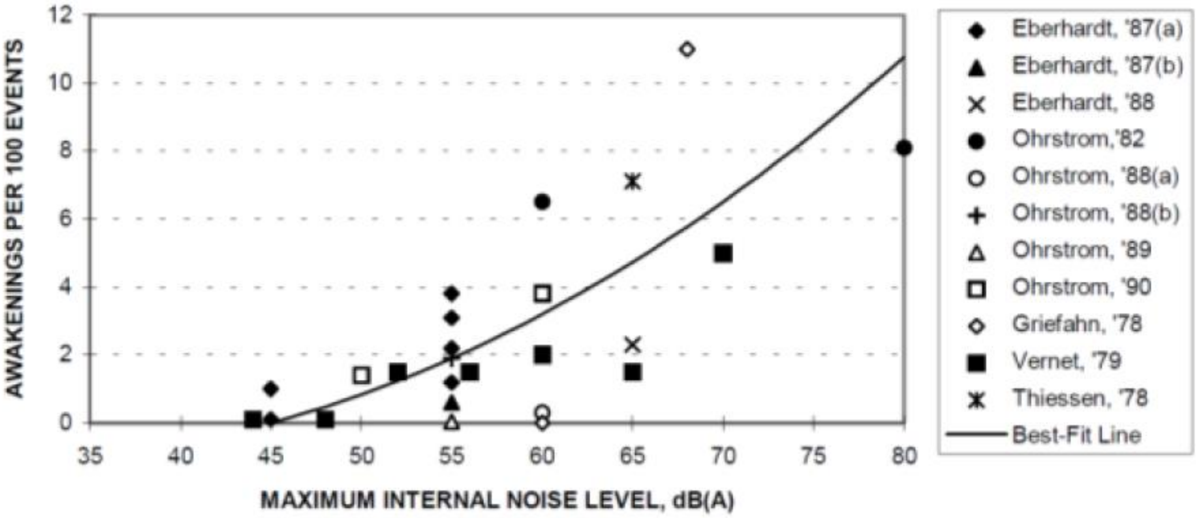

Figure 1.Summary of studies of sleep awakening events to maximum noise levels, reproduced (Bullen, 1996)

This study is particularly important in quantifying the relative difference expected in comparing different noise level criteria. For example a maximum level of 65 dB(A) L_{max} compared to 45dB(A) L_{max} is predicted to have a sleep awakening rate of 5% compared to 0%.

Similarly, the FICAN (1997) created a dose-response curve for predicting awakening in 1992 based on laboratory experiments. Experts believed that these laboratory sleep studies showed higher sleep disturbances compared to field studies where people can sleep in a familiar environment. This curve was later updated in 1997 based on various undertaken field studies regarding sleep interference near airports based on the following formula/graph.

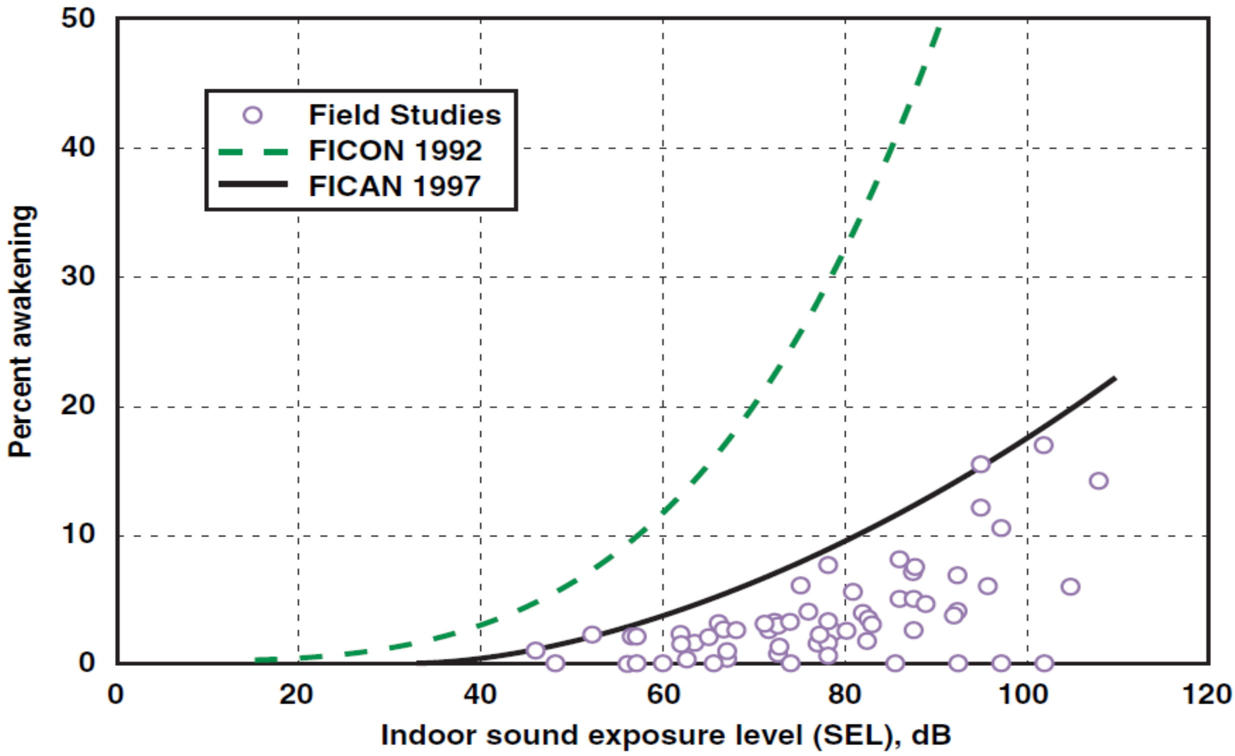

Figure 2. Recommended Sleep Disturbance reproduced (Miller, 2013)

Again, the results of the FICON study can be used quantifying the relative difference expected in comparing different noise level criteria. For example a maximum level of SEL 65 dB compared to SEL 45 dB is predicted to have a sleep awakening rate of 8% compared to 3%; which again is a 5% difference.

The author notes that there is no clear correlation between L_{Amax} and SEL noise levels. For example, if an aeroplane flies faster, the L_{Amax} stays the same, but the SEL reduces. Nonetheless, both the graphs in Figure 1 and Figure 2 indicate an exponential growth of sleep disturbance correlating to the noise level.

Similar research undertaken into the effects of sleep disturbance amongst children is an area to which not much research has been undertaken; and therefore, the author was unable to find any research relating to sleep awakenings amongst babies and young infants.

3.5 Motivation

Motivation is a difficult to quantify in relation to noise and noise level. Research undertaken by FICAN (2000) members indicates a reduced level of motivation and attention span for children due to uncontrollable noise. However, from anecdotal evidence, high noise levels do not always negatively impact motivation of children. For example, helicopters, military aircraft and trains are typically objects of interest for young children and this type of noise can have positive effects on the enthusiasm of children. In fact, the Royal Children's Hospital in Melbourne has a view deck of the helipad as a design feature (James, 2012).

3.6 Annoyance

There have been many studies regarding the effect of noise to annoyance of adults. However, again, children's annoyance due to noise is a relatively under researched area.

Children may be aware of noise without necessarily being annoyed by it. In Shield's (2013) study, older children were found to be more aware of noise, while younger children found noise more annoying. The most annoying noise sources were trains, motorbikes, trucks and sirens. The results of Shield's research indicate that intermittent loud noise events cause most annoyance to children while at school.

3.7 Ambient noise levels

Young children are typically exposed to noisy environments, which may or may not be caused by themselves.

Shield (2003) found that the ambient noise level in an occupied primary school classroom was closely related to the pupil activity. The measured activity levels ranged from 56 dB(A) L_{eq} (silent activity) to 77 dB(A) L_{eq} when the pupils were engaged in noisier activities. The author note that the undertaken research was at schools and activities that children get involved in at schools are typically different compared to childcare centre. However, there is conflicting evidence as to whether or not ambient noise levels are affected by the age of children (Shield, 2003), which suggest that similar noise levels can be expected in childcare centres.

Noting the above, the AAAC guideline for Childcare centre acoustic assessments (AAAC,2010) notes sound power levels of 10 children playing ranging from 77 dB(A) to 90 dB(A) for children aged 0 to 2 and 3 to 6 years respectively; which is a quite significant difference of up to 13 dB(A).

4. WHICH NOISE LEVEL SHOULD WE USE?

The author's literature research and involvement on various similar projects with intermittent noise sources, highlights the wide variety of noise level describers for intermittent noise sources. Examples of applied describers are $L_{Aeq;day/night}$, $L_{Aeq;T}$, $L_{Amax;Fast}$, $L_{Amax;Slow}$, SEL, Loudness, DNL, $L_{A5;T}$, $L_{A90;T}$, etc.

In practical terms, most, if not all, standards relate directly to an A-weighted noise level (L_{Aeq} or L_{Amax}), which may not always be appropriate for specific events. Current usage of A-weighted noise levels has often been criticized because it may not entirely describe the "noisescape" which often has a more direct relationship to experienced noise levels (e.g. loudness) and annoyance in some sense (Adams, 2014).

In his research, Adams, also suggest that a future addition of at least some of the available psychoacoustic metrics would strengthen the ability to address the perceived annoyance. The majority of the paper indicates that Loudness would be a suitable description for noise levels and the perceived impact. However, Adams eventually proposes to use the L_{A5} noise level suitable limit, rather than the mean or maximum value of loudness. However, the paper questions itself that the question is over which time period this should be taken and that the nominated limit is rather arbitrary (Adams, 2014).

Secondly, most research indicates that number of events or L_{Aeq} noise levels is a better qualifier for people's reactions to aircraft noise. Research undertaken in France for noise levels from TGV pass bys suggested that the number of noise events exceeding 70 dB(A) was a more relevant noise index than L_{Amax} (Shield, 2003).

Unfortunately, the proposed, L_{Aeq} or L_{A5} parameters would not be directly transferable to the subject of this paper. Intermittent or once a week noise events are generally loud, and if measurements are taken of a sufficiently long period, average noise levels would remain reasonable.

Therefore, this paper proposes to propose an L_{Amax} target for intermittent noise sources. These noise levels have a direct link to a certain noise event and are therefore easily to quantify. Even more, Children's perceptions of the acoustic environment relating to annoyance was shown to be directly linked to L_{Amax} noise levels.

Using SEL has a suitable target has also been considered. However, SEL noise levels are typically difficult to quantify during the design stages. A SEL noise level is dependent on much information that is typically not easily available for design teams, in contrary to L_{Amax} noise levels, which can easily be modelled using Sound Power Levels and 3D noise propagation modelling using SoundPLAN or similar.

5. PROPOSED TARGETS

Nominating a suitable design target for childcare centres has proven to be a difficult thing, especially when there many stakeholders involved. Typically, none of these stakeholders are the actual children. Therefore, as the acoustic consultant, it should be your duty to protect the children from any future noise induced harm; while maintaining a fair balance between realistic targets. Setting criteria too coarse in application usually leads to conservative design and excessive material cost in acoustic controls and facade construction. Setting criteria too fine and prescriptive in application can over-complicate design processes and confuse the design team, and/or reduce production economies of scale (James, 2012).

5.1 Sleeping areas

As noted before in this paper, there are still a lot of unknowns of the effects of (high) noise levels on a child's immediate and future health. Furthermore, there is limited scientific evidence regarding the impact of intermittent noise events on adults. Therefore, current criteria for noise impacts are mostly based on direct and indirect effects of noise on health are related to prevent noise induced hearing loss, minimize sleep disturbance.

Nonetheless, for hospital design, Available research suggest that a maximum limit of no less than 65 dB(A) L_{max} is a suitable limit for hospital wards (James, 2012).The author proposes to adopt a similar level for sleeping areas in childcare centres. Noise at this level has a limited chance of causing awakenings and a negligible change of causing any health impacts. Although, James' research (as are most other as well) is mainly focused on adults, from anecdotal evidence it appears that children are typically unaffected by noise events of up to 65 dB(A) L_{max}. Further research may be required to confirm this.

5.2 Play areas

Unfortunately, for activity spaces there is no research available to determine suitable noise levels. The majority of research discusses learning interference due to noise; which is typically of (semi-)steady-state nature. The author queries whether a once in a week event would actually have an impact on speech development or any other non-auditory health effects.

Important is to focus on the cumulative effects on hearing impairment in adulthood. Much is still unknown about these effects. Undertaking research in these areas is underfunded; and additionally it would be unethical to expose children to high noise levels. Nonetheless, various research papers suggest that ambient noise levels in classrooms are already in the order of 75 dB(A) L_{eq}, due to children's activities.

Therefore, this paper proposes to adopt a design target of 75 dB(A) L_{max} for play areas. Noise levels will be similar to environments than children are already exposed to on a daily basis, although the noise spectrum may be different, child activities typically are dominated by high frequency noise. Furthermore, noise levels due to single noise events are well away from the critical limit of 85 dB(A) L_{max} which is typically linked to noise induced hearing loss.

6. CONCLUSION

There is a need for further research to exam the effects of intermittent high noise levels on sleep disturbance and learning effects on young infants. This type of research has been undertaken for adults; however, results obtained with adults cannot necessarily be translated to children.

Setting suitable criteria for intermittent noise sources appears to be a difficult thing, because so many other factors other than a noise level appear to have an influence on sleep disturbance, speech and annoyance. However, in order to provide reference and starting point guidance for new developments,

The authors' experience is that setting a maximum limit of 65 dB(A) L_{max} for sleeping areas and 75 dB(A) L_{max} for play areas is an appropriate design target for child care centres near intermittent noise sources, such as near helipads or (goods-) railway lines. However, design execution will of course vary depending on the type of noise source, building arrangement, extent of glazing, facade system etc.

Additionally, the author recognizes that current research and design standards are inconclusive and that further research into the effect of intermittent high noise level sources is required to determine suitable design standards.

REFERENCES

Adams. K, 2014, *New insights into perception of aircraft and community noise events*, Inter-noise Melbourne

American Academy of Pediatrics, 1999, *Handbook on children's environmental health*, American Academy of Pediatrics

Association of Australian Acoustical Consultants 2010, *AAAC Guideline for Child Care Centre Acoustic Assessment*.

Australian Government, National Occupational Health and Safety commission, 2000, *National standard for occupational noise*, Canberra

Berglund, B., Lindvall, T. & Schwela, D.H. 1999, *Guidelines for Community Noise*, World Health Organisation, Geneva.

Bullen, R., Hede, A. & Williams, T. 1996, *Sleep Disturbance Due to Environmental Noise: A Proposed Assessment Index*, Acoustic Australia, vol. 24 no. 3.

Department of Planning and Community Development (VIC), 2012, *Planning requirements for heliports and helicopter landing sites*, Practical Note 75, Melbourne

Department for Education and Skills (UK), 2014, *Acoustic Design of Schools: A Design guide*, Building Bulletin 93, London: The Stationery Office

Environmental Protection Authority (NSW), 1999, *Environmental Criteria for Road Traffic Noise*, Environmental Protection Authority, Sydney.

Federal Interagency Committee on Awakenings from Sleep, 1997, *Effects of Aviation Noise on Awakenings from Slee*p, US.

Federal Interagency Committee on Aviation Noise, 2000, *Research into effects of aircraft noise on Classroom Learning*, US.

Institute of Acoustics (IOA) and the Association of Noise Consultants (ANC) 2015,*Acoustics of Schools: a design guide*, UK

James, A. and Zoontjens, L., 2012, *Helicopter Noise Impacts on Hospital Development Design*, Proceedings of Acoustics 2012 – Fremantle WA

Lancet et al. 2014; *Auditory and non-auditory effects of noise on health*, doi:10.1016/S0140-6736(13)61613-X.

Miller, R, 2013, *The Effects of Noise on People*, Los Angeles World Airports LAX Part 161 Study, Burlington, MA USA

Maxwell, Dr. L.E. and Evans, Dr. G.E, Unknown, *Design of Child Care Centers and Effects of Noise on Young Children*, Retrieved 2 July 2016, http://www.designshare.com/Research/LMaxwell/NoiseChildren.htm

Shepherd, D., Welch, D., Dirks, K. N., & Mathews, R., 2010, *Exploring the Relationship between Noise Sensitivity, Annoyance and Health-Related Quality of Life in a Sample of Adults Exposed to Environmental Noise.* International Journal of Environmental Research and Public Health, doi:10.3390/ijerph7103580

Shield, B.M. and Dockrell J.E. 2003, *The effects of noise on children at school: a review*, J. Building Acoustics 10(2), 97-106, 2003