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Major infrastructure project construction noise and vibration management in Sydney

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ABSTRACT

Over the last decade Metropolitan Sydney has been changing as a multitude of major infrastructure projects are constructed, including South West Rail Link (Glenfield to Leppington), Sydney Metro North West, Sydney Metro City and South West, WestConnex, Parramatta Light Rail, Northern Beaches Hospital road upgrade and Western Sydney Airport. Projects in the pipeline include Sydney Metro West and Sydney Metro Western Sydney Airport, Western Harbour Tunnel, Warringah Freeway Upgrade, Beaches Link to name a few in Sydney. Minimising construction noise and vibration impacts has been a significant consideration in the planning and management of these projects. This paper looks at how construction noise and vibration has been managed on some large infrastructure projects over the last decade. It looks at what some of the key learnings have been and how we might take this forward into a 'golden century of infrastructure investment'.

1 INTRODUCTION

There are many constraints when establishing and operating large construction worksites, 24 hours a day, seven days a week in suburban Sydney and the CBD. For tunnelling projects beneath sensitive receivers, the noise source is invisible, but audible and at times inescapable, 24-hours a day. Where projects integrate with the live road or rail network, managing the progression of works in a safe environment without impeding road or rail traffic can mean lots of work must be conducted during the sensitive night period. Often there is conflict between sensitive receivers surrounding a construction site. Commercial receivers may prefer construction work to occur outside business hours, while residential receivers would prefer works to occur during the day when they are likely to be out. Over the last eighteen months this has been turned upside-down with COVID 19 restrictions meaning residential areas are occupied 24 hours a day.

2 MANAGING IMPACTS

2.1 Construction hours

In NSW standard construction hours are recommended in the *Interim Construction Noise Guideline* (ICNG) (DECC, 2009) as Monday to Friday 7am to 6pm and Saturday 8am to 1pm, with no work on Sundays or public holidays. Some large infrastructure projects may have the Saturday hours extended through the Planning Approval, allowing works until 6pm.

In April 2020 construction hours were extended to support the construction industry during COVID-19. The Environmental Planning and Assessment (COVID-19 Development—Construction Work Days) Order (No 3) 2021 allows work on Saturday afternoon, Sunday and public holidays, with the exception of rock breaking, rock hammering, sheet piling, pile driving or similar activities. Whilst this allowed construction sites to plan works with social distancing in mind and minimise lost productivity, it also meant that some residential receivers were exposed to construction noise and vibration seven days a week, when they were confined to their homes. Respite was not available to them by temporarily escaping their homes.

With most infrastructure projects, works are required outside standard construction hours to allow for safe work and to minimise disruption, such as when the project is near a road or rail corridor. One of the primary considerations when managing construction work is ensuring all works that can be scheduled during standard hours are, so that the works required out-of-hours are limited. Where works must be out of hours, impacts can be managed further by prioritising works to less sensitive time periods like weekday evenings and weekend days and evenings. Where all reasonable and feasible mitigation has been exhausted, respite may need to be provided in the form of meal vouchers or movie tickets; or alternative accommodation, where the impacts may significantly disturb sleep.

There is a lack of consistency about how out of hours works are managed across different infrastructure projects, and this can lead to uncertainty when planning and costing construction. In addition, weekend night works can be

prohibited in the Environment Protection Licence (EPL). On major road projects interfacing with the existing arterial road network prohibiting weekend night works may conflict with the opportune timing for Road Occupancy Licences. While the goal is to minimise impact in the short term, the result can mean extended noise impacts and disruption to the road network as the works take longer to be completed. Table 1 demonstrates the variation in the number of nights of out of hours works on several major infrastructure projects over the last five years.

Table 1: Limitations of the number of nights of out-of-hours works

WestConnex M8 [EPL 20772] (2016)	Rozelle Interchange [EPL 21278] (2018)	Parramatta Light Rail [EPL 21347] (2019)	M6 EPL 21600 (2021)
3 consecutive evenings or nights per week	2 consecutive evenings and/or nights per week	Works on a maximum of 4 nights in any 7 day period;	2 consecutive evenings and/or nights per week;
4 evenings or nights per week	3 evenings and/or nights per week;	Noise sensitive receivers provided with 3 respite nights following 4 nights of work in any 7 day period	3 evenings and/or nights per week; and
10 evenings or nights per month	10 evenings and/or nights per month.		10 evenings and/or nights per month.
High impact works no more than 2 evening or nights per week	Only between 6:00pm on Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and 7:00am the following day		Only between 6:00pm on Mondays, Tuesdays, Wednesdays, Thursdays, Fridays and 7:00am the following day (unless permitted by another condition of this licence) Not between 6:00pm on Saturdays, Sundays or Public Holidays and 7:00am the following day (unless permitted by another condition of this licence)
Not in infrastructure approval SSI 6788	Not in infrastructure approval SSI 7485	Consistent with infrastructure approval SSI 8285	Not in infrastructure approval SSI 7485

There needs to be a benchmark for how out of hours works can proceed so that contractors can adequately plan and cost out of hours work and to ensure impacts on sensitive receivers are equitable. Identification of this issue during the environmental assessment stage can make a difference in the certainty of how a project is managed. Decision makers are given the opportunity to consider this as part of the impact assessment and include relevant conditions in the approval, as demonstrated in the Parramatta Light Rail example in Table 1.

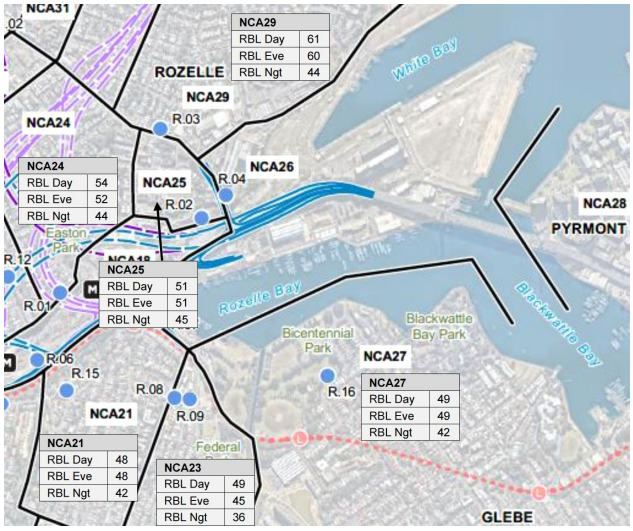
There needs to be more flexibility in allowing out of hours works on weekend and public holiday evenings and nights. This would allow for works that need to be completed over a weekend Road Occupancy License, which may be required for utility works or tie-ins with the major arterial roads connected to a project. A weekend Road Occupancy Licence can reduce the overall duration of required out of hours works as works completed over a weekend shutdown period do not require the establishment and demobilisation of traffic controls for each shift. Further, the duration of Road Occupancy License on Saturday and Sunday nights can be longer, for example from 8 pm each night and until 8 am on Saturdays and/or Sunday. This would assist with efficiencies and may reduce the overall project impacts.

2.2 Noise Management Levels/ Objectives

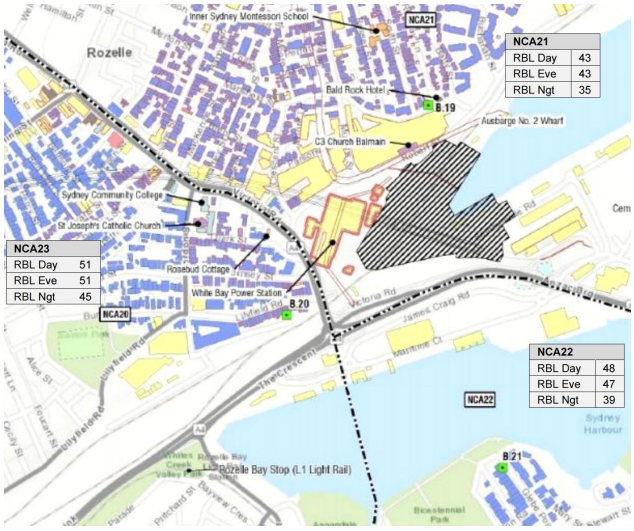
The ICNG is the key guideline for assessing and managing infrastructure construction noise. For airborne noise, outdoor noise objectives are established relative to the rating background level (RBL) for residential receivers. During standard hours the objective or Noise Management Level (NML) is RBL plus 10 db. Outside standard hours the NML is RBL plus 5 dB. Background noise levels can vary substantially across a project, sometimes for a single worksite. Subsequently the NMLs will also vary for residential receivers across the project, which may be perceived as unfair. In contrast to this, other sensitive receivers such as schools and commercial receivers have fixed NMLs, as does ground-borne noise for residential receivers.

In NSW, industry practice has been used to take noise logging from a representative location and apply it across a noise catchment area (NCA), for receivers that are exposed to a similar acoustic environment. While practical, this approach often leads to disparities in the NMLs applied to different NCAs for a project, with large differences in the NMLs in adjacent NCAs. This could result in a significant challenge in managing noise impacts as higher noise exceedances may be predicted at receivers along the same road but further away from the work areas. It is also noted that established NCAs may sometimes be not representative of areas with similar background noise levels as they extend over several hundred meters. This problem can be exacerbated where there are multiple projects in one area, such as in Rozelle/ Lilyfield. To illustrate this Figure 1 presents a comparison of RBLs adopted for similar NCAs for two infrastructure projects in Sydney: Rozelle Interchange; and Sydney Metro West to illustrate this issue. The differences in RBLs across the NCAs could be due to shielding from road traffic noise or seasonal variation in noise levels.

Figure 1 shows that from the M4-M5 Link EIS (Rozelle Interchange) the RBL at night in NCA21, 23, 24 and 25 varies from 36 dB(A) in NCA23 to 45 dB(A) in NCA25, which is a 9 dB variation for residences that are in a similar acoustic environment, apart from properties directly exposed to the arterial roads. The same receiver areas are assessed as just one NCA (NCA20) in the Sydney Metro West EIS, with RBL 45 dB(A) at night. NCA27 for Rozelle Interchange is the same as NCA22 for Sydney Metro West, yet there is a 3 dB difference in the RBL at night, less during the day and evening period. Of greater significance is the differences between NCA29 for Rozelle Interchange compared with Sydney Metro West's NCA21, which cover the same receiver areas, yet there is 11 dB difference in the RBL at night, 18 dB during the day and 17 dB during the evening. These two projects will be under construction concurrently, working to different NMLs due to variations in the RBLs.



Rozelle Interchange NCAs and RBLs



Sydney Metro West NCAs and RBLs

Figure 1: Comparison of RBLs from two projects across similar noise catchment areas

2.3 Alternative to adopting NMLs relative to RBLs

As an alternative to adopting NMLs based on background noise monitoring, a more equitable approach might be to apply fixed NMLs based on the typical land uses and development in an area. An example would be the 'typical existing background noise levels' referenced in Table 2.3 of the NPfI (see Table 2). The NMLs would be based on existing planning instruments and features of the area that might influence ambient noise levels. Alternatively, the Roads and Maritime *Construction Noise and Vibration Guideline* and the Transport for NSW *Construction Noise and Vibration Strategy* allow background noise levels to be estimated based on Appendix A of Australian Standard 1055.3-1997. While this standard was superseded in 2018 and no longer references the estimated average background sound levels. Both examples present a reasonable estimate of background noise for the purpose of managing construction.

The above approaches are simpler and more cost-effective to implement and would not subject to seasonal variations in the measured RBLs, or poorly selected NCAs. More importantly, they would provide a more even-handed, standardised approach for the community.

Table 2: Typical existing background noise levels from NSW *Noise Policy for Industry*

Receiver category	Typical planning zoning – standard instrument*	Typical existing background noise levels	Description
Rural residential	RU1 – primary production RU2 – rural landscape RU4 – primary production small lots R5 – large lot residential E4 – environmental living	Daytime RBL <40 dB(A) Evening RBL <35 dB(A) Night RBL <30 dB(A)	**Rural** – an area with an acoustical environment that is dominated by natural sounds, having little or no road traffic noise and generally characterised by low background noise levels. Settlement patterns would be typically sparse. Note: Where background noise levels are higher than those presented in column 3 due to existing industry or intensive agricultural activities, the selection of a higher noise amenity area should be considered.
Suburban residential	RU5 – village RU6 – transition	Daytime RBL<45 dB(A) Evening RBL<40 dB(A)	**Suburban** – an area that has local traffic with characteristically intermittent traffic flows or with some limited commerce or industry. This area often has the
	R2 – low density residential R3 – medium density residential E2 – environmental conservation E3 – environmental management	Night RBL <35dB(A)	following characteristic: evening ambient noise levels defined by the natural environment and human activity.
Urban residential	R1 – general residential R4 – high density residential B1 – neighbourhood centre (boarding houses and shop-top housing) B2 – local centre (boarding houses) B4 – mixed use	Daytime RBL> 45 dB(A) Evening RBL> 40 dB(A) Night RBL >35 dB(A)	**Urban** – an area with an acoustical environment that: • is dominated by 'urban hum' or industrial source noise, where urban hum means the aggregate sound of many unidentifiable, mostly traffic and/or industrial related sound sources • has through-traffic with characteristically heavy and continuous traffic flows during peak periods • is near commercial districts or industrial districts • has any combination of the above.

Notes: *As cited in Standard Instrument – Principal Local Environmental Plan, New South Wales Government, Version 15 August 2014. RBL = rating background noise level.

2.4 Managing vibration impacts

Infrastructure projects in NSW apply *Assessing Vibration: a technical guideline* (DECC, 2006) to manage human disturbance impact from construction generated vibration. The guideline is based on the British Standard BS 6472 and establishes clear objectives for managing disturbance to building occupants. The assessment is simplified by starting with an initial screening test for vibration disturbance to building occupants, based on the maximum peak particle velocity (pop, mm/s). Where this is triggered, further analysis can be undertaken to determine the Vibration Dose Value (VDV).

There is no Australian Standard or clear guideline for assessing the likelihood of damage to buildings or structures from construction vibration. To ensure certainty during the construction phase of an infrastructure project, a clear assessment approach is needed during the environmental assessment phase. This ensures vibration impact from the project can be reviewed and determined with confidence and appropriate Conditions of Approval set by the planning approval.

Guidance for road and rail projects can be taken from the *Construction Noise and Vibration Guideline* (RMS 2016) and the *Construction Noise and Vibration Strategy* (TfNSW 2019), respectively. Australian Standard AS 2187: Part 2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives* recommends the frequency dependent guideline values and assessment methods given in British Standard BS 7385-2:1993 *Evaluation and measurement for vibration in buildings* for the prevention of minor or cosmetic damage occurring in structures from ground vibration. Appendix A of the *Construction Noise and Vibration Strategy* describes the screening process for as-

sessing vibration impact on structures on the basis that for most construction activities involving intermittent vibration sources such as rock breakers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz, and usually in the 10 Hz to 100 Hz range. A conservative vibration damage screening level (ppv, mm/s) per receiver type which includes a 50 percent reduction in the level to account for dynamic magnification due to resonance, is given as:

- Reinforced or framed structures: 25.0 mm/s
- Unreinforced or light framed structures: 7.5 mm/s.

Where the predicted and/or measured vibration is greater than shown above, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics and magnification due to resonance of the structure should be completed to determine the applicable vibration limit.

Heritage buildings found to be structurally sound should not be assumed to be more sensitive to vibration and should therefore be assessed to the screening criterion for reinforced or unreinforced structures above, depending on the structure. An inspection by a structural engineer should be completed to confirm whether a heritage building or structure is structurally unsound. In the case that it is not structurally sound, a more conservative cosmetic damage objective based on Line 3 of Table 1 in German Standard DIN 4150 should be considered (see Table 3).

Table 3: Typical existing background noise levels from NSW *Noise Policy for Industry*

Line	Type of structure	Vibration velocity, mm/s				
		Structure foundation, all directions (x, y, z) at frequency of			Topmost floor, horizontal direction (x,y)	Floor slabs, vertical direction (z)
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz[a]	All frequencies	All frequencies
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Line 1 or 2 and have intrinsic value (e.g. buildings listed on a heritage register)	3	3 to 8	8 to 10	8	20[b]

Notes: a. At frequencies above 100 Hz, the guideline values for 100 Hz can be applied as minimum values
b. It may be necessary to lower the relevant guideline value to prevent minor damage.

Source: German Standard DIN 4150-3:2016-12 Vibrations in buildings Part 3: Effects on structures

2.5 Construction noise and vibration guidelines, strategies and standards

Transport for NSW has developed several documents for managing construction noise and vibration from their infrastructure projects, including:

- Construction Noise and Vibration Guideline (Roads and Maritime (RMS) 2016)
- Construction Noise and Vibration Strategy (ST-157/4.1) (Transport for NSW (TfNSW) 2019)
- Chatswood to Sydenham - Construction Noise and Vibration Strategy (Sydney Metro 2016)
- Sydney Metro West Construction Noise and Vibration Standard (SM-20-00098866) (Sydney Metro 2020)

These documents provide clear guidance on the noise and vibration objectives for construction of major road and rail projects, and also on the minimum requirements for mitigating and managing impacts, where they occur. Where all reasonable and feasible mitigation measures have been applied and there are still residual impacts, the documents provide a procedure for managing the impacts through notification, monitoring and provision of respite.

The management approach for residual impacts using ‘additional mitigation measures is similar with most of the documents, as shown in Table 4.

Table 4: Comparison of Additional Mitigation Measures from current guidelines and strategies

Construction Noise and Vibration Guideline (RMS)	Construction Noise and Vibration Strategy (TfNSW)	Chatswood to Sydenham - Construction Noise and Vibration Strategy (Sydney Metro)	Sydney Metro West Construction Noise and Vibration Standard SM-20-00098866 (Sydney Metro)
Notification (letterbox drop or equivalent) Specific notification (letterbox drop (or equivalent) to identified stakeholders) Phone calls Individual briefings	Periodic notification (project update), Specific notification (letterbox drop, phone call, individual briefing)	Letterbox drops Phone calls and emails Specific notifications	Letterbox drops Phone calls and emails Specific notifications
Verification (monitoring) Individual briefings give opportunity to comment Respite Offers Respite Period 1 & 2 Duration Respite Alternative Accommodation	Verification monitoring Individual briefings give opportunity to comment Respite offer Alternative Accommodation Respite periods/ Duration Reduction	Monitoring Individual briefings give opportunity to comment Project specific respite offer Alternative Accommodation	Monitoring Individual briefings give opportunity to comment Project specific respite offer Alternative Accommodation

The additional mitigation measures summarised above are triggered by the emergence of construction noise above the RBL. There are some differences in the way additional mitigation measures are applied by the different documents, as shown in Table 5.

2.6 Cumulative noise impact

Cumulative noise and vibration assessments and construction fatigue have been included in the Secretary's Environmental Assessment Requirements (SEARs) of almost all recent infrastructure projects. The expectations for cumulative noise assessment are vague. Should the assessment be quantitative or qualitative? How detailed does it need to be? How do consecutive impacts (i.e. one project after another, sometimes resulting in many years of impact) compare to cumulative impacts (i.e. two or more projects impacting the same receiver at the same time)? Adding noise levels together does not provide a true picture of cumulative impacts. Often only limited information about works on other projects is available, so the cumulative assessment becomes a mix of qualitative and quantitative estimate of impact. Sometimes not all adjacent projects would have the requirement for cumulative impacts and it is not clear who is responsible for mitigation measures (e.g. who is paying for alternative accommodation or respite offers?). For concurrent works, impacts can be managed through scheduling and coordinating high noise works, out of hours works and respite periods.

When should a receiver be considered fatigued? Is it after a year of construction, or after several years with varying projects? Is a receiver impacted by a fixed worksite with substantial acoustic treatment (acoustic sheds, noise barriers, heavy vehicle limits), such as at Rozelle Interchange or Barangaroo more construction fatigued than a receiver near a linear construction project, where works come and go, but treatment is limited and there are multiple weekend works (e.g. rail possession or road occupancy weekends), such as on the St Peters Interchange (WestConnex) or Sydney Metro South West Corridor. What is a reasonable way of managing construction fatigue? This grey area of impact assessment requires further consideration to develop some protocols that protect sensitive receivers, whilst still allowing construction to be completed safely and cost effectively. Direction and coordination need to come from a central organisation such as the Environment Protection Authority to ensure that the approach is adopted across all major construction projects.

2.7 Contractor managed construction

One of the big changes to the way construction noise and vibration impacts are managed has been the development of online noise and vibration prediction and management tools allowing contractors to self-manage construction noise and vibration impacts. Based on three dimensional models, tools such as Gatewave (Renzo Tonin & Associates), Noisecheck (EMM Consulting), Snapshot (Arup) and KNOWnoise (Hutchison Weller) have been developed to allow specific work areas and activities to be assessed as construction works progress. These tools, when used with care and appropriate training, can be of great benefit to the contractors understanding of how works can impact the surrounding receivers, especially at night. Construction methodology can be altered and the works reassessed to reduce impacts and costs such as alternative accommodation when works are required during the night period.

Table 5: Comparison of triggers for Additional Mitigation Measures from current guidelines and strategies

Construc-tion hours	Construction Noise and Vibration Guideline (RMS)	Construction Noise and Vibration Strategy (TfNSW)	Chatswood to Syden-ham - Construction Noise and Vibration Strategy (Sydney Metro)	Sydney Metro West Construction Noise and Vibration Standard SM-20-00098866 (Sydney Metro)
Notifications (including letterbox drops or equivalent)				
Std H	RBL + 20	RBL + 20	RBL + 20	RBL + 15
OOH P1	RBL + 10	RBL + 10	RBL + 10	RBL + 5
OOH P2	RBL + 5	RBL + 0	RBL + 10	RBL + 5
Monitoring				
Std H	RBL + 20	RBL + 20	RBL + 20	RBL + 25
OOH P1	RBL + 20	RBL + 20	RBL + 20	RBL + 15
OOH P2	RBL + 10	RBL + 10	RBL + 10	RBL + 15
Community engagement (individual briefing)				
Std H	-	HNAL > 75	-	-
OOH P1	RBL + 30	RBL + 20	RBL + 30	RBL + 35
OOH P2	RBL + 20	RBL + 20	RBL + 20	RBL + 25
Respite periods, respite offer				
Std H	-	-	-	-
OOH P1	RBL + 10	RBL + 20	RBL + 30	RBL + 25
OOH P2	RBL + 10	RBL + 20	RBL + 20	RBL + 15
Alternative Accommodation				
Std H	-	-	-	-
OOH P1	-	-	-	-
OOH P2	RBL + 30	RBL + 30	RBL + 30	RBL + 25

Notes: Std H = standard construction hours; OOH = out of hours, i.e. outside standard construction hours; OOH Period 1 = Monday to Friday 6pm to 10pm, Saturday 1pm to 10pm, Sunday & Public Holidays 8am to 6pm, as defined in TfNSW and RMS documents; OOH Period 2 = Monday to Friday 10pm to 7am, Saturday 10pm to 8am, Sunday & Public Holidays 6pm to 8am

3 CONCLUSIONS

After ten years of major infrastructure construction in NSW, some of the key lessons learned can be taken forward into a ‘golden century of infrastructure investment’. The lessons need to consider the many constraints when establishing and operating large construction worksites, 24 hours a day, seven days a week in suburban Sydney and the CBD and in rural areas. Where conflict arises between different sensitive receiver types surrounding a construction site, resolution must be sought through consultation and negotiation to achieve a suitable outcome for the majority. Flexibility with out of hours works arrangements needs to be applied consistently across projects. Background noise levels can vary substantially across a project, sometimes for a single worksite. This can re-sult in an inequitable outcome for some residential receivers or a perceived unfairness in the way different resi-dential receivers are treated. Conversely, other sensitive receivers such as schools and commercial receivers have fixed indoor noise management level as does ground-borne noise for residential receivers. As an alternative to adopting NMLs based on background noise monitoring, consideration should be given to fixed noise levels based on the typical land uses and development in an are To prevent the likelihood of minor or cosmetic damage occurring in structures from construction generated ground vibration, a conservative vibration damage screening level (ppv, mm/s) per receiver type can be used. The screening level is based on British Standard BS 7385-2:1993 *Evaluation*

and measurement for vibration in buildings and takes into consideration dynamic magnification due to resonance. For heritage buildings that have been identified as structurally unsound, a more stringent screening level based on German Standard (Table 1, Line 3) should be adopted. Transport for NSW guidelines and strategies for managing construction noise and vibration provide clear guidance on the noise and vibration objectives for construction of major road and rail projects, but also on the minimum requirements for mitigating and managing impacts, where they occur. More discussion is needed to define and manage cumulative impacts and construction fatigue as current guidelines and requirements do not facilitate the expected outcome. Construction noise and vibration management tools developed by acoustic consults to allow contractors to assess and manage their own worksites have been a major innovation in construction noise and vibration assessment.

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