Straddle Carrier and Construction Noise Management on Level Crossing Removal Project - Caulfield to Dandenong

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ABSTRACT

The Level Crossing Removal Project - Caulfield to Dandenong was established to remove nine level crossings along a busy rail line in the south-eastern Suburbs of Melbourne. The primary method of constructing the raised rail viaduct was using a Straddle Carrier, a large transportation rig that anchored itself to the bridge piers and placed the bridge spans into place without the need for ground clearance.

This paper provides insight on the construction activities carried out for the project, and the associated noise management techniques. Predictive modelling and real-time noise monitoring were used to influence construction methods and scheduling to actively manage noise impacts to the community.

Sound Power Levels were determined for the Straddle Carrier, derived from measurements, to enable prediction of noise impacts. The model was calibrated to align with the measurements taken at representative distances from residential properties. The paper elaborates a case study with the use of field measurements, real-time monitoring and predictive modelling of unique construction techniques in a challenging environment to successfully manage noise effects.

1 INTRODUCTION

The Level Crossing Removal Project - Caulfield to Dandenong (LCRPCTD) was established to remove nine level crossings along the Cranbourne / Pakenham railway line in the south-eastern Suburbs of Melbourne. Through the management of construction noise, WSP assessed the noise impacts from specialised construction techniques required to install bridge spans in a rail corridor that shared a boundary with residential properties on both sides.

Traditional methods of bridge span installation were not feasible due to the proximity of residential dwellings, lack of space immediately outside the corridor, and the need to operate trains continuously at-grade below the viaducts during construction. The viaduct segments were therefore delivered to a central compound in the Melbourne suburb of Murrumbeena, where the segments were assembled to form the bridge spans. The equipment consisted of large Gantry Cranes in the central compound which acted as a home base for the Straddle Carrier, used to place the bridge spans into place without the need for ground clearance. It was the first time this machinery has been used in residential Australia.

Straddle Carriers are seldom used for construction, and have limited documentation on the associated noise emissions – the information was insufficient for any predictive noise modelling exercise, therefore requiring detailed measurements of the equipment. The only noise data provided by the Straddle Carrier operators (KONE Cranes and DEAL) was associated with a single diesel generator mounted onto the rear of the body, producing 70 dBA at 7 m. This data formed the basis for all noise modelling predictions prior to the arrival of the plant in 2017, which was insufficient information for detailed assessments and for assisting construction scheduling to minimise environmental impacts on the community.

Noise impacts associated with the construction compound at Murrumbeena Station included the delivery of viaduct segments, assembly of segments with steel re-enforcements, operation of two Gantry Cranes and the Straddle Carrier. The work undertaken included background noise assessments, preparation of an acoustic model using SoundPLAN v7.4 and the prediction of noise levels from typical construction scenarios involving the concrete span construction and Straddle Carrier.

Field measurements of the Straddle Carrier were proposed during the commissioning phase in mid-2017, to calibrate the acoustic model and add any noise sources emitted from the carrier that were not previously documented, including the operation of the Support Beam, Transfer Beam and span placements. The measured data was processed to back-calculate the SWLs input into the 3D model. Following the first pass of the updated acoustic model, the validation process was conducted and the model was adjusted based on measurements taken during viaduct installation works (full operation of the Straddle Carrier and auxiliary equipment). Alarms and sirens were assessed as part of the wider noise impacts from the construction compound but were not used during Straddle Carrier operations and therefore not assessed.

The following sections focus on the specialised equipment, the associated plant and noise emissions and noise model validation details. The noise management associated with the Murrumbeena compound is also briefly discussed.

1.1 PROJECT BACKGROUND

In July 2016, the project released a public video animation detailing the construction process of the raised rail viaduct using the Straddle Carrier and supporting plant (https://www.youtube.com/watch?v=lGtIIDAgwi4). Whilst the delivery and assembly of viaduct spans within the compound followed standard construction techniques, the process of span installation on piers involved the use of a Straddle Carrier, two Gantry Cranes, a Support Beam and a Transfer Beam. Figure 1 presents a photo taken of the main specialised plant.

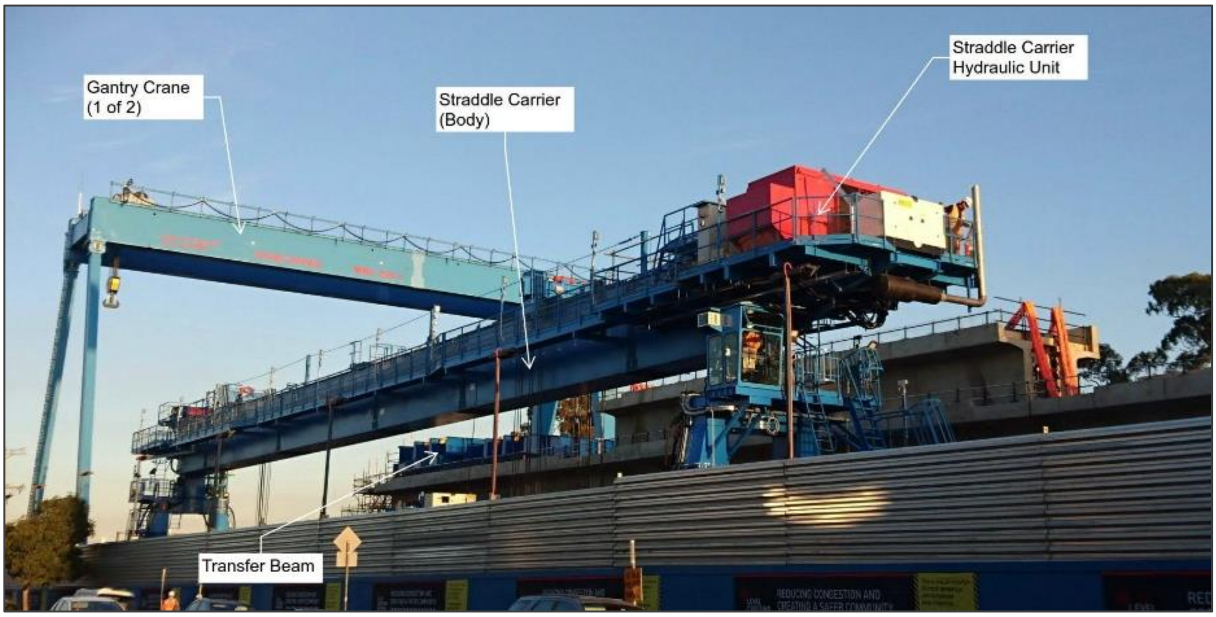


Figure 1: Gantry Crane, Straddle Carrier and Transfer Beam (Support Beam not shown)

During the early stages of the project, all construction scenarios modelled involving the Straddle Carrier had been assessed during the day (7am-6pm) and evening periods (6pm-10pm) only. However, due to project and safety requirements, the operation of the Straddle Carrier had to be altered to allow for 24-hour operations within the corridor.
As directed by the project team and the EPA, noise modelling scenarios were produced to predict the impacts from the construction compound, and operation of the Straddle Carrier during the night time period, defined as 10pm to 7am. However, the noise predictions were based on the limited data available at the time and was not expected to produce accurate results. The Straddle Carrier span placement process was considered continuous works, with the Straddle Carrier considered able to work 24 hours a day. Progress consisted of up to 2 placements of spans per day, with each span placement to take approximately 2 to 6 hours (weather dependant).

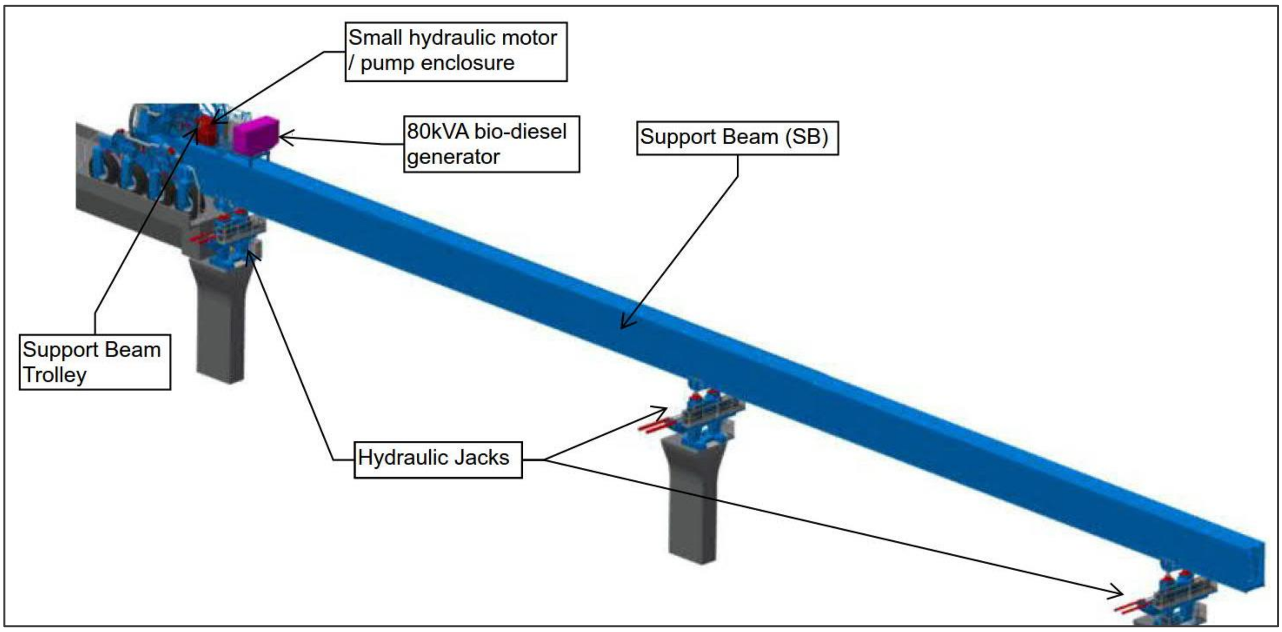
2 CONSTRUCTION EQUIPMENT

Table 1 presents the identified specialised plant and the associated key noise sources.

Table 1: Key noise sources from specialised plant

Specialised Plant	Associated Key Noise Sources	Supplied Information / Comments
Straddle Carrier (SC)	- Hydraulic Unit (L114-DU-AK-A-500) - Hydraulic Unit Exhaust - 30kVA Bio-Diesel Generator - Winch Motor - Radiator Fan	- Model No. L114-SC 435/40 (DEAL) - SC noise quoted to be 70dBA at 7m
Gantry Crane (GC)	- Diesel Generator - Winch Motor - Bogie	- Diesel Generator 5000kVA: 72 dBA at 5m - Hoisting Trolley SMT20: 74 dBA at 5m - Bogie: No significant noise emissions
Support Beam (SB)	- SB trolley (motor, trolley movement and diesel generator) - SB movement and support legs (hydraulic jacks and associated small motors)	- SB trolley found to produce less noise than SC - Audible increases observed during SB movements as internal actuators and chains were in motion for short periods (15 min), however these were considered insignificant and therefore ignored.
Transfer Beam (TB)	- TB movement (hydraulic ram)	Observed to emit insignificant noise as it is operated at very low velocity using hydraulic rams. It was therefore excluded from the assessment.

A diagram of the Support Beam and supporting plant is presented in Figure 2. A photo of the Straddle Carrier and associated components are presented in Figure 3.



Source (LCRPCTD Project, 2017)
Figure 2: Support Beam (SB) and supporting plant

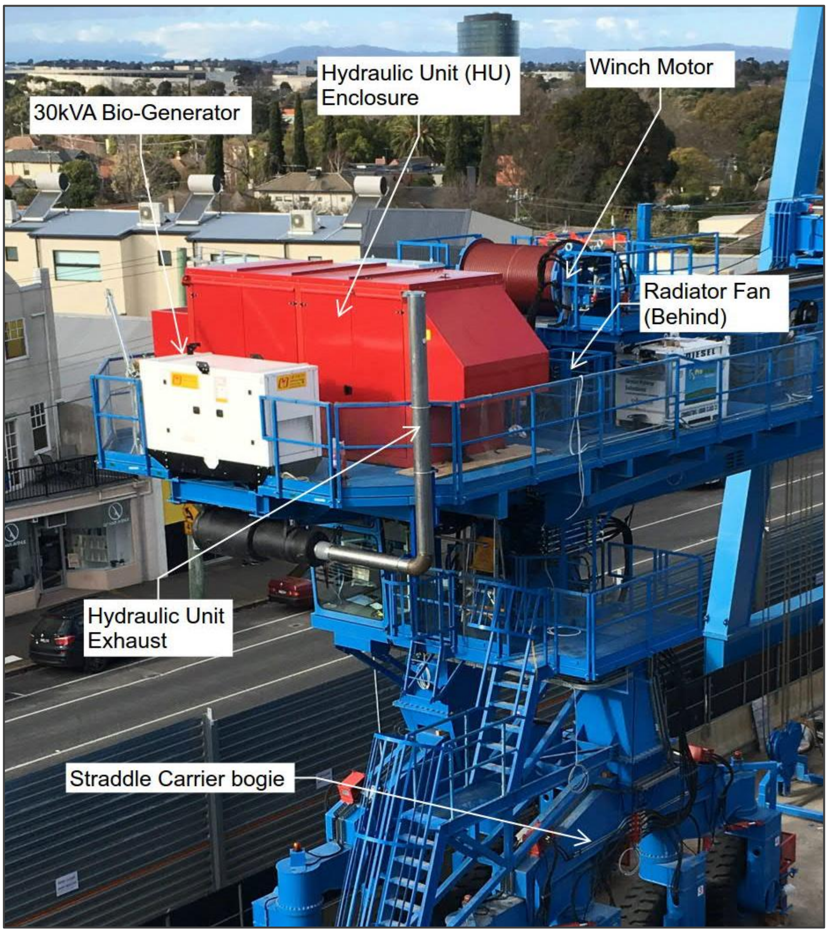


Figure 3: Straddle Carrier (SC) and key identified noise sources

3 DETERMINATION OF NOISE SOURCES

3.1 Sound Power Levels

A series of simple calculations were conducted to convert the measured Sound Pressure Levels (SPLs) to Sound Power Levels (SWLs) for noise modelling. The first pass of calculations (prior to the arrival of the equipment on site) were based on limited manufacturer data and was deemed not suitable for impact assessments. This suggested that the dominant noise sources required more thorough analysis to produce an accurate model. The highest noise sources were identified as the Hydraulic Unit enclosure outlet and the associated exhaust outlet.

The Hydraulic Unit was corrected using simple plane source calculations and designed as an industrial building in SoundPLAN. This allowed the modeller to account for the specific inlet and outlet dimensions and associated cowls, which were orientated in opposite planes for the inlet and outlet, respectively. Measurements were taken carefully to limit the influence of extraneous sources (such as the adjacent Bio-Diesel Generator) when the Hydraulic Unit was in operation.

Near field measurements were undertaken at several locations within 1m to 2m to develop a small dataset of noise emissions to compare against desktop calculations and finally the SoundPLAN model. The model was built to account for the asymmetrical layout of the noise emitting plant on the Straddle Carrier. Details of the procedure used to calculate the Hydraulic Unit exhaust SWL are presented in Section 3.1.1 of this paper. Table 2 presents the SWLs developed for the specialist plant and used in the acoustic model.

Table 2: Sound Power Levels (SWLs)

Element	Sound Power Levels (SWL), *dB*							Overall SWL, *dBA*
	Octave Band Centre Frequency, *Hz*							
	63	125	250	500	1k	2k	4k	
Straddle Carrier HU Exhaust	92	113	108	90	91	87	84	102
Straddle Carrier HU Outlet	97	98	104	105	102	98	94	106
Straddle Carrier HU Outlet (at engine idle)	87	87	84	83	80	77	69	85
Straddle Carrier HU Inlet	96	93	91	89	87	82	74	91
Straddle Carrier HU Enclosure Body	90	92	90	89	89	85	79	93
Straddle Carrier Biogen	97	93	94	90	87	85	78	93
Support Beam Biogen	108	92	97	94	92	89	83	97
Straddle Carrier Winch	94	91	90	84	84	77	69	88
Straddle Carrier Radiator Fan	85	86	88	86	86	81	75	89
Gantry Crane Diesel Generator	91	92	87	88	88	86	79	92
Gantry Crane Winch Motor	88	87	84	93	92	89	83	96
Gantry Crane Bogie	89	83	78	76	76	76	73	82
Straddle Carrier Biogen Outlet + Exhaust	83	78	81	76	75	72	67	80
Support Beam Biogen Outlet + Exhaust	85	80	83	78	77	74	69	82
Straddle Carrier Biogen Inlet	90	85	83	77	76	72	65	81
Support Beam Biogen Inlet	92	87	85	79	78	74	67	83

3.1.1 Hydraulic Unit Exhaust

For the purposes of simplifying the model, the exhaust body (fitted with a silencer) was not accounted for. The steel exhaust stack had a diameter of 200mm with the outlet discharging approximately 2m from the elevated walkway (refer Figure 2). The exhaust was fitted with a small silencer; however, the design details were not available for analysis.

Measurement data taken of the exhaust in the form of emission spectra is presented in Figure 4. Strong tones were emitted at 100Hz and 200Hz from the exhaust. This was a constant source of noise as the HU did not vary with engine speed (rpm). SWL calculations were based on measurements taken at 1m as the 2m measurement was close to the Hydraulic Unit inlet resulting in heavy noise influence.

Calculations of the exhaust outlet were undertaken using Equation 1 (Bies and Hansen, 2003), taking suspected directivity and distance losses into account:

$$L_w = L_p - DI_\theta + 10\log_{10} 4\pi r^2 + 10\log_{10}\frac{400}{pc} + A_e \quad (1)$$

Where L_w is Sound Power Level, L_p is Sound Pressure Level, DI_θ is the directivity index, r is radius (distance from source to receiver), p is density of the exhaust gas, c is the speed of sound in the exhaust gas at stack exit (343m/s) and A_e is excess attenuation. Appropriate assumptions of gas properties, and a directivity index of 90° were made to determine the SWL. The directivity index is determined by Figure 9.27 in Bies and Hansen's Engineering Noise Control, using a calculated Strouhal number at 90° to the normal of the stack, which was adopted at the measurement position.

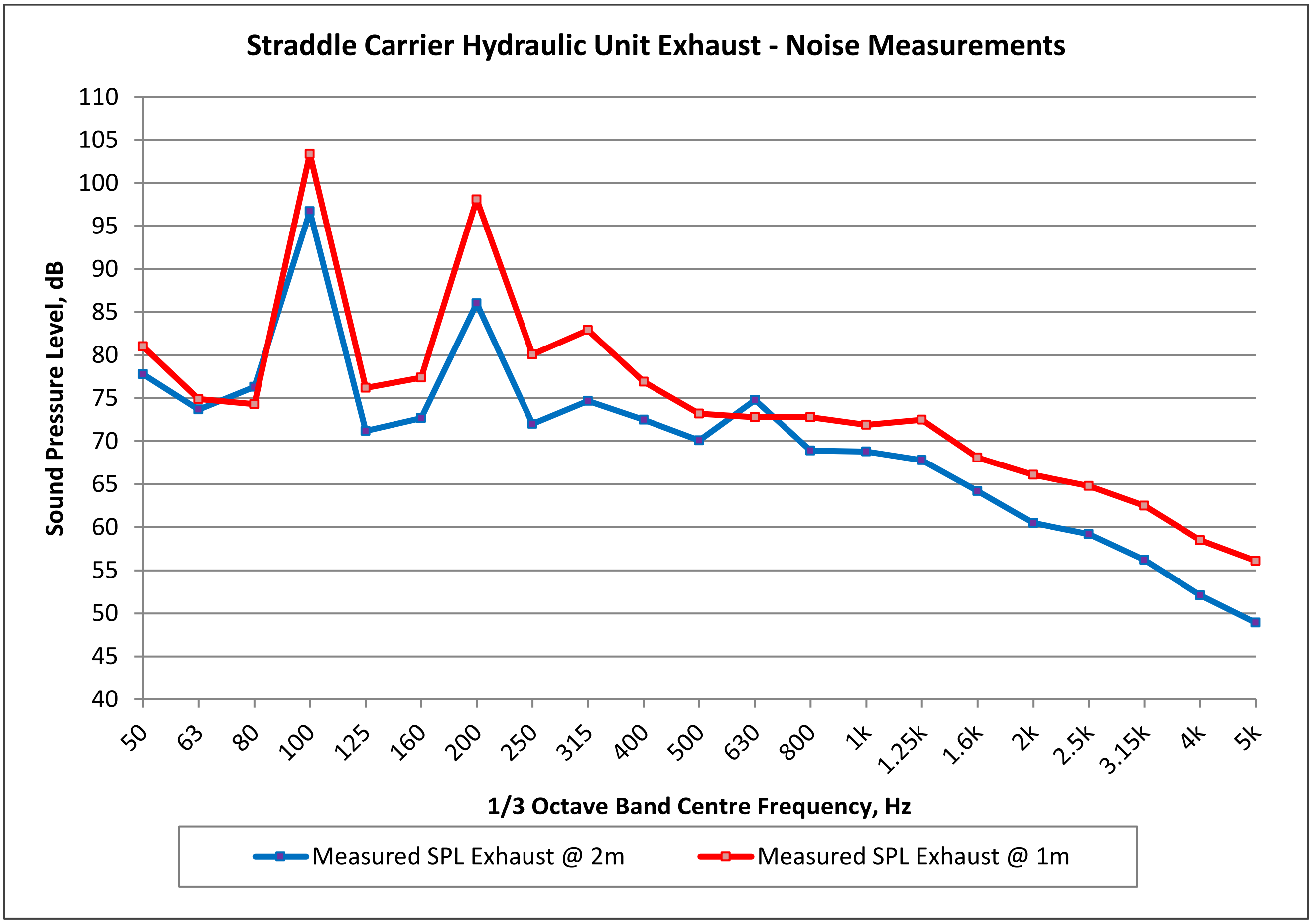


Figure 4: Measured SPL of Straddle Carrier Hydraulic Unit exhaust in near field positions

3.2 Noise Model Validation

Following the calculation process to develop SWL information of the specialised equipment, the noise model was rebuilt to represent the known layout and operation of the Straddle Carrier span placements. The model showed good correlation between modelled and measured noise levels at near field positions. The next step was to validate the model at far field positions, representative of the nearest noise sensitive residences. The far field validation test positions undertaken during the Straddle Carrier span placements are presented in Figure 5.

Straddle Carrier operations were measured at a representative location of the nearest resident's backyard. Straddle Carrier SPLs were measured to be 68 dBA (constant noise) whereas noise levels during span placements were observed to be in the range of 71 to 74 dBA (for approximately 20 mins). As a comparison, WSP Acousticians measured 90 dBL_{Amax} from a passing freight train and diesel passenger locomotives (single pass by) at SC Validation #4. This was approximately 15m from the live rail corridor. While not conducive to this assessment, the comparison between the existing train noise and the Straddle Carrier noise were beneficial to the project team for the purposes of community consultation.

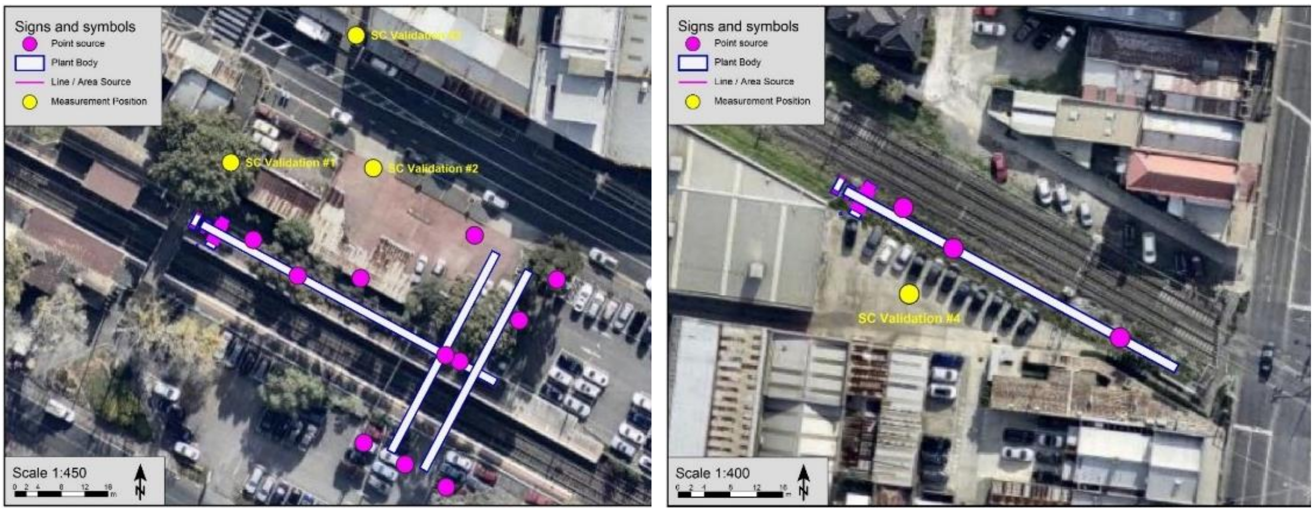


Figure 5: SoundPLAN model and validation positions

The model underpredicted at all far field locations by -4 dB, likely to be caused by an underestimation of directivity, shielding and reflection effects from the nearby environment. Table 3 presents the validation comparison between the modelled and measured results.

Table 3: Validation Measurements

Receiver	Model SPL, *dB*	Measurement SPL, *dB*	Difference, *dB*
Near field measurement 1 - Behind HU at 1m	90	90	0
Near field measurement 2 - Next to HU at 1m	86	85	-1
Near field measurement 3 - HU Outlet at 1m	105	105	0
Near field measurement 4 - HU Inlet at 1m	91	90	-1
SC Validation #1 – 12m from SC Body	70	74	4
SC Validation #2 – 22m from SC Body *	65	71	6
SC Validation #3 – 41m from SC Body	66	70	4
SC Validation #4 – 9m from SC Body	67	71	4
Calibration factor			**4**

* Excessive extraneous noise was present during the measurement at this position. This measurement was excluded from assessment.

The model was calibrated by +4dB to correct far field modelling results for construction noise impact predictions at affected residences. Causes for the difference in noise levels between the model and the measurements at far field positions can be attributed to the following:

- Distance, atmospheric propagation and ground absorption were less influential at longer distances than what the model suggested.
- Measurements may have been influenced by extraneous mid-low frequency noise, despite the best efforts of the acousticians to avoid this.
- Directivity effects from the Hydraulic Unit exhaust system and other plant were underestimated.
- The far field measurements were taken when the SC was in operation, potentially increasing noise emissions which would account for the model underprediction, as the near field measurements (which the model was built on) were taken during 'dry' commissioning tests.

Once validation was complete, new noise contours were generated. These new contours were presented to the EPA to demonstrate the validated model and the new prediction results. The new information was used by the environmental and stakeholder management team to develop respite protocols. A comparison between the preliminary noise model (2016) and the validated noise model (2017) is shown below in Figure 6. The model predicted that the nearest residences (along boundary of the rail corridor) could experience up to 74 dBA (externally) when span placements were conducted immediately adjacent to the noise sensitive property.

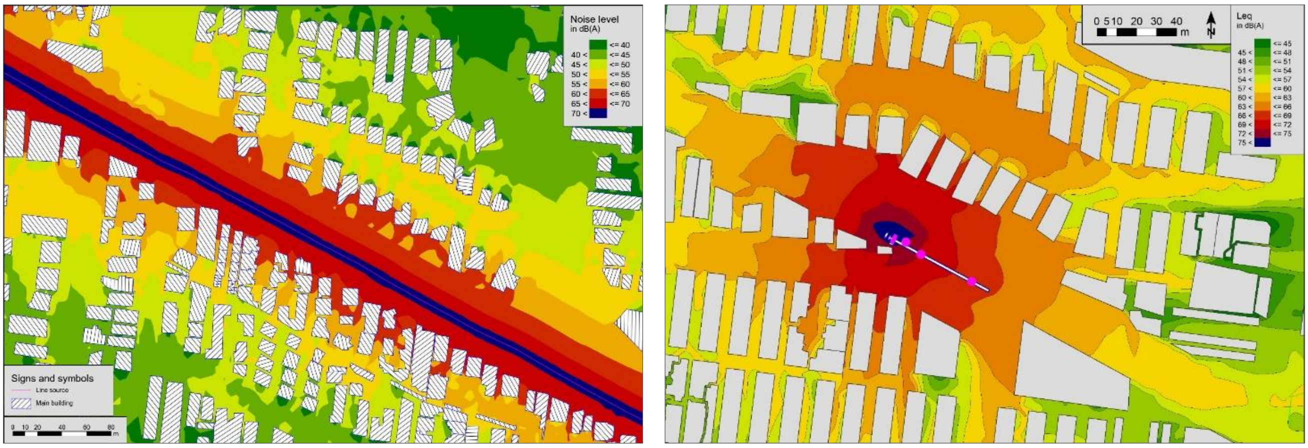


Figure 6: Comparison between the preliminary 2016 contours vs. the validated contours (2017)

4 COMPOUND NOISE MANAGEMENT

Traditional construction techniques were used at the compound to deliver the segments, assemble the segments using steel re-enforcements and concrete grouting. However, these activities, combined with Gantry Crane and Straddle Carrier movements created the potential for adverse noise impacts to the surrounding dwellings. 24-hour operation of the carrier meant that the equipment operated within the compound during the night. Scheduling of construction activities within the compound were therefore a critical part of noise management.

Predictive noise modelling was used as an effective tool to inform the noise impacts for various construction activities and scenarios to the construction, environment and stakeholder engagement teams. Using predictive modelling and impact assessments, the construction team altered the schedule to avoid noisy activities at night (such as segment deliveries and concrete grinding), and accommodate them during day periods. The location of stationary noise sources (such as generators), were modified to maximise physical separation between the source and receivers. Use of alarms were also carefully managed to avoid sleep disturbance to residents where feasible. Permanent noise barriers were installed around the compound to minimise noise impacts at ground level from moving sources (such as forklifts and telehandlers).

Figure 7 compares the predictive noise model outcomes based on the initial construction schedule during night, with the final construction schedule with all noise management measures implemented. This noise impact assessment, along with early engagement with the construction team, resulted in minimising noise impacts significantly, and avoided relocating residents for extended periods of time.

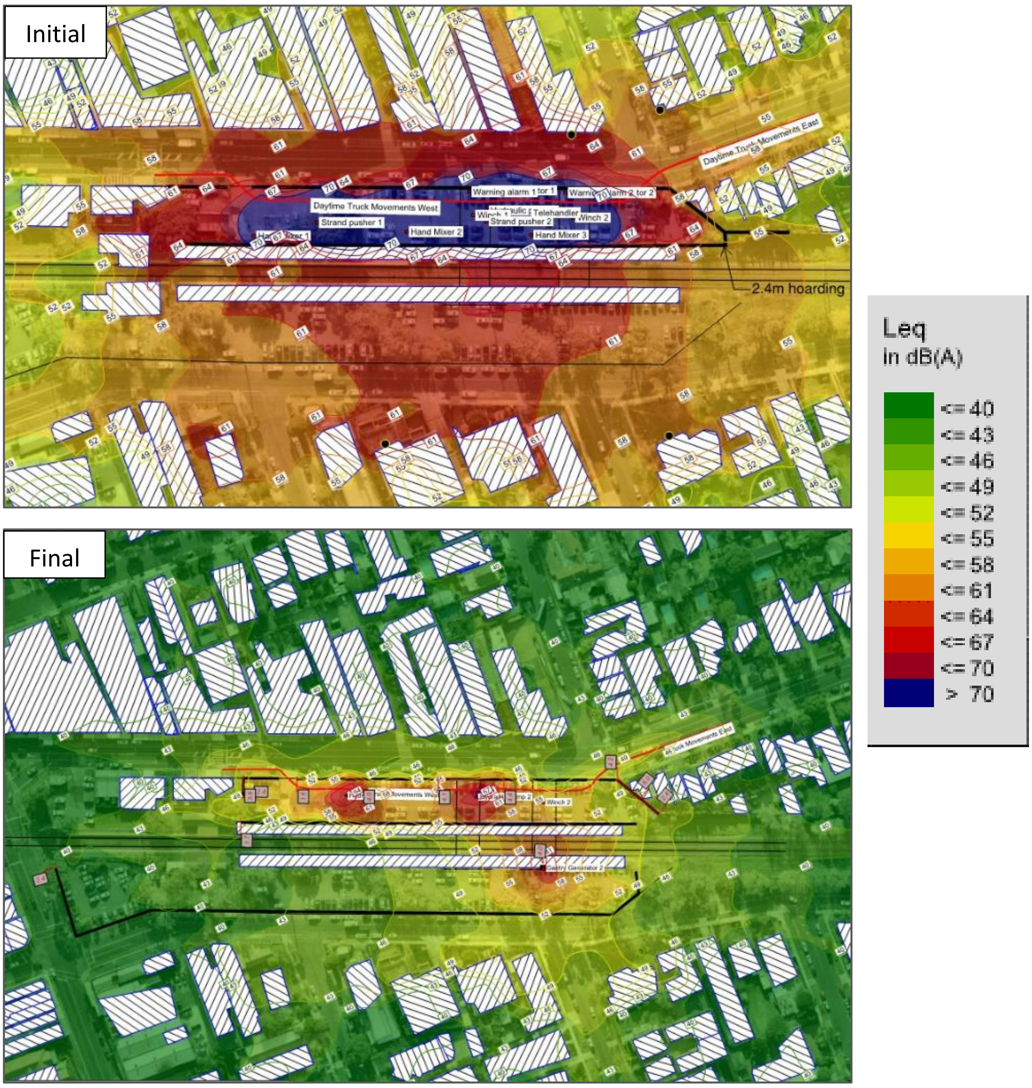


Figure 7: Comparison between the initial Murrumbeena compound model (2016) vs. the updated model (2017)

During construction within the Murrumbeena compound, it was important to undertake noise measurements for the entire course of the construction process to adequately manage impacts and respond to queries. To enable this, smart real-time noise monitoring systems were installed permanently on the boundaries of the compound. NTi Audio's *Noise Scout* (https://www.noisescout.com/) online real-time noise monitoring web portal was used to remotely monitor noise levels by the acoustic, construction, environmental and stakeholder management teams to pro-actively manage impacts, and respond to any queries if they occurred. The web portal had the ability to dynamically alter the logging interval and adjust alarm and notification levels.

Figure 8 shows the web interface of the monitoring system implemented. Active noise monitoring with 1 second logging data uploads indicated that train pass-bys produced higher L_{Amax} levels compared to most of the construction activities, thereby providing the ability to identify causes for peaks in noise levels during any 24-hour period. The construction team was also able to turn off idling equipment within compound to readily observe the reduction in noise on the web portal. Predictive noise modelling, along with active real-time noise monitoring were proven to successfully minimise noise queries within the surrounding community.

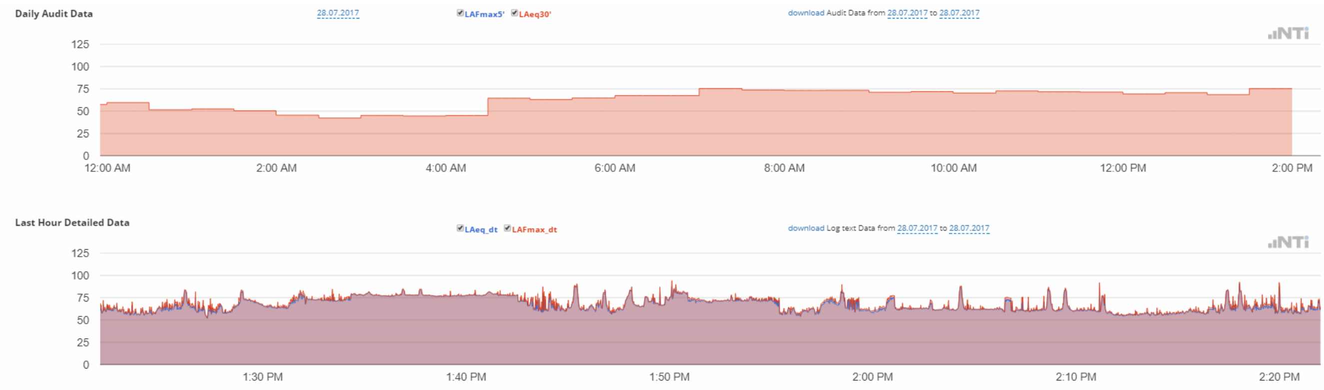


Figure 8: Online noise monitoring database, logger positions and histogram

5 CONCLUSIONS

This paper highlights the need for detailed assessments of special construction techniques such as viaduct span placements using a Straddle Carrier, particularly where noise data is typically unavailable. These detailed assessments and validated noise models greatly assist the construction scheduling to minimise environmental impacts on the community from these major works.

The main findings are:

- At the boundary of the rail corridor, noise levels were measured to be within the range of 71 to 74 dBA during span placements (with all Straddle Carrier and Support Beam equipment operating). The noise model predictions were validated to provide good correlation with measurements. As a comparison, passing diesel locomotives on existing infrastructure were measured to be 90 dBL_{Amax} at the same location.
- The main noise source identified is the Straddle Carrier hydraulic unit and associated exhaust system. The Straddle Carrier emitted the highest noise levels during span placements.

Site visits were restricted due to the safety risks involved with the elevated moving platform. No acousticians were allowed to be standing on the Straddle Carrier or any other plant when in motion. Access to the Straddle Carrier during normal operation would allow for extensive near field measurements and may account for small changes in noise signatures. Only at-ground measurements were taken during typical operation of the Straddle Carrier.

Further works can include the following:

- Further measurements (both near and far field) and time understanding the Straddle Carrier operation, in order to clarify asymmetrical noise emissions due to the layout of the noise emitting plant.
- Additional near field measurements of the winch motors under load. It was observed the motor noise emissions did increase under load when lifting the span, however all non-essential crew were restricted from standing on the Straddle Carrier deck during the lifts / span placements.

ACKNOWLEDGEMENTS

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REFERENCES

Bies, David A. and Hansen, Colin H. 2003. *Engineering Noise Control – Theory and Practice.* 3rd ed. London: Spon Press (Taylor and Francis Group).
Level Crossing Removal Authority, 2016. YouTube Video: *Caulfield to Dandenong: Construction at Murrumbeena*. Australia.
Noise Scout – Unattended noise monitoring web portal. https://www.noisescout.com/. NTi Audio.