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Comparison of Kilde Report 130 Rail Noise Modelling Predictions for SoundPLAN 4.2 and 6.5

Mark Batstone (1), Rhys Brown (2) and Jennifer Uhr (3)

(1) Network Systems & Capability, QR Network Pty Ltd, Brisbane, Australia
(2) Bassett Acoustics, part of AECOM, Brisbane, Australia
(3) Heggies Pty Ltd, Brisbane, Australia

ABSTRACT

Rail noise predictions in Queensland have historically been undertaken using a DOS-based implementation of the SoundPLAN program. Rail noise levels modelled using this DOS program have been validated with measured noise levels throughout the history of its use. This DOS package has been superseded by Windows-based implementations of SoundPLAN. Queensland Rail Network has commissioned a study to compare the modelling results between the currently accepted DOS-based version of SoundPLAN and the latest Windows-based implementation. The outcomes of the study contained in this paper demonstrate why QR Network is now able to accept Windows SoundPLAN results for rail noise prediction projects within Queensland. Equivalent confidence in the modelled noise levels reduces the amount of noise monitoring required at affected properties, leading to a more efficient and sustainable use of available acoustical resources in Queensland. Such reliable noise modelling results therefore enable more efficient delivery of mitigation measures to sensitive areas than can be achieved with reliance upon measurement results.

INTRODUCTION

Historically Queensland Rail (QR) has required rail noise modelling in Queensland to be undertaken using the 1984 Nordic Rail Prediction Method - Kilde Report 130 (Ringheim 1984) as implemented in SoundPLAN 4.2 (a DOS-based software package). Since its adoption as the preferred rail noise modelling software by QR, it has been consistently validated against rail noise measurements with an accuracy threshold of ± 2 dBA for Queensland locations typically within 100 metres of the rail alignment (Heggies, 2007 & ERM, 2001).

In more recent years, Windows-based versions of SoundPLAN have been released and supported rather than the previous DOS-based versions. Neither SoundPLAN's manufacturer nor suppliers have provided support for SoundPLAN 4.2 since the year 2000. Communications with these companies has suggested that no quality control process was in place to ensure consistency and/or accuracy between the SoundPLAN versions (certainly, for at least the Kilde Report 130 algorithms). From these discussions, it was clear that the responsibility for validating the new SoundPLAN versions lay with the respective railway manager and/or environmental regulator. It was for this reason that QR Network initiated the investigations presented in this paper.

The implementation of the Kilde Report 130 within the Windows-based versions of SoundPLAN has never been formally validated for rail applications in Australia. In order for rail noise modelling to be undertaken within Queensland in the most efficient manner, a process of validation was required for the latest Windows-based SoundPLAN implementation of Kilde Report 130 for Queensland conditions.

Rail noise modelling results from SoundPLAN 4.2 and SoundPLAN 6.5 have been calculated and compared by two independent acoustic consultancies with the aim of validating SoundPLAN 6.5 for use on rail projects within Queensland. The effect of various modelling techniques, inputs and assumptions has also been investigated as part of this comparison study.

MODELLING METHODOLOGY

General

The Nordic Rail Traffic Noise prediction method - Kilde Report 130 (Ringheim 1984) is the current QR endorsed rail noise modelling method. The Kilde Report 130 is the earliest standard in the series of Nordic rail noise modelling methods. It was superseded in Scandinavian countries by NMT96 (Ringheim 1996) and Nord2000 (Jonasson 2001).

The Kilde Report 130 method enables both $L_{Aeq,24hour}$ and L_{Amax} noise levels for rail movements to be predicted. In Queensland, current legislative planning ("target") levels are based on both parameters.

For the purpose of this study a small test section was extracted from an existing SoundPLAN rail model for a current rail upgrade project. The extracted section was trimmed to approximately 100 metres either side of the rail line. The section was approximately 600 metres long and contained 33 noise-sensitive receiver locations. The receivers varied in distance from 10 metres to 95 metres from the rail source line. Non-sensitive buildings such as commercial buildings were removed from the scenario where there were no noise sensitive receivers in the vicinity. [Figure 1]

The original noise model from which the test section was taken was previously created in SoundPLAN 6.4.

Geo-files containing the test section were extracted from this original model and a SoundPLAN 6.5 model was created for the simplified situation. The various components of the model were then exported in both DXF and ASCII formats to enable data to be imported into SoundPLAN 4.2. SoundPLAN 6.5 is the most recent Windows-based release of the SoundPLAN modelling package and SoundPLAN 4.2 was the final DOS-based release.

Figure 1. Modelled Section of Track

Source Levels

Both the SoundPLAN 6.5 and 4.2 implementations of the Kilde Report 130 method require the input of noise level corrections specific to each type of rollingstock modelled.

Rollingstock noise data was sourced from QR data. Details of the modelled rollingstock are shown in Table 1.

Table 1. Rollingstock Source Data

Train Type	*Length (m)*	*Speed (km/h)*	*L_{Amax} @25 m (dBA)*	*SEL @25 m (dBA)*
6 Car EMU	144	80	86	91
Single Diesel Locomotive (Notch 8)	18	80	94	91
Freight Consist	750	80	85	90

Source (Heggies, 1998)

Noise data for the freight consist in Table 1 is based on a consist length of 150 metres.

The SoundPLAN noise-level corrections for Kilde Report 130 were independently derived by both consultants. Both consultancies' noise level corrections produce predicted noise levels which match the QR rollingstock data for a receiver located 25 metres from a straight rail source line with propagation over hard ground.

Single train pass-bys were modelled to enable a direct comparison between modelled results. Straight track, gentle curves and tight curves were modelled with the associated track corrections summarised in Table 2.

Table 2. Curve Corrections

Curve Type	*Curve Radius (m)*	*Correction (dBA)*
Straight	> 500	0
Gentle	300 to 500	+3
Tight	< 300	+8

Source: (Schall 03)

Assumptions and Exclusions

Acoustically hard (reflective) ground was assumed throughout the study to be representative of typical maintenance access roads found on railway corridors.

To more accurately represent the true acoustic height, single diesel locomotives were modelled with the source string (or SoundPLAN "object" elevation) located at 3.5 metres above Top-Of-Rail (or the SoundPLAN "ground" elevation). EMU and Consist were modelled with the source string located at Top-Of-Rail. The Kilde Report 130 method lifts the actual modelled noise source to 0.5 metres above the rail source string.

Although the test section did not contain any curves with a radius of less than 500 metres, curve corrections were applied to the rail source line within the test section and modelled to ensure a robust comparison exercise.

Due to advances in the modelling software, additional variables are included in the calculation settings for SoundPLAN 6.5 that are not included in SoundPLAN 4.2. Whilst the calculation settings differed between SoundPLAN 4.2 and 6.5, the settings were chosen to match and represent current practice used in rail modelling in Queensland.

In particular, Kilde Report 130 includes a + 3 dBA facade correction for receivers located 1 metre from a facade. However, the handling of the facade correction and reflections typically differs between the two SoundPLAN versions.

In SoundPLAN 4.2, there is no option to add a + 3 dBA facade correction (as contained in Kilde Report 130) to the predicted noise level. Instead, for this modelling exercise, the number of reflections has been set to 10 with the reflection from the receiver's facade included in the predicted noise level. In other words, the facade effect is calculated rather than adding a standard + 3 dBA correction.

In SoundPLAN 6.5 the user may choose whether or not SoundPLAN adds the + 3 dBA facade correction in accordance with Kilde Report 130. The user may also (independently) choose whether or not the reflection from the receiver's facade is suppressed. For this study SoundPLAN 6.5 calculations were setup to add the + 3 dBA facade correction and suppress the receiver's facade reflection. The effect of these settings has been investigated as part of this study.

Additionally SoundPLAN 6.5 typically defaults to calculating only one reflection. This default setting was used for all calculations unless otherwise stated.

The search radius for the SoundPLAN 6.5 calculations was limited to 500 metres.

These modelling parameters and assumptions have been chosen to reflect the modelling technique considered to be the most common and are consistent with legislation applied in Queensland (Environmental Protection (Noise) Policy, EPP(Noise) 1997). The EPP(Noise) states that railway noise shall be assessed 1 metre from the most exposed façade of the sensitive place.

RESULTS

The noise modelling results for both SoundPLAN 4.2 and 6.5 from the two consultancies were compared for consistency. For both SoundPLAN 4.2 and 6.5, the predicted noise levels produced by each consultant were comparable and showed good agreement.

A comparison of the SoundPLAN 4.2 and 6.5 predictions showed the prediction differences for all but one (1) receiver were within ± 2 dBA for both consultants' results. Furthermore, more than half of the receivers had prediction differences within ± 1 dBA.

A brief analysis of the prediction differences is shown for three scenarios in Tables 3, 4 and 5.

Table 3. EMU Straight Track Prediction Differences

Statistical Parameter	*Consultant 1*		*Consultant 2*	
	$L_{Aeq,24hr}$ (dBA)	*L_{Amax} (dBA)*	*$L_{Aeq,24hr}$ (dBA)*	*L_{Amax} (dBA)*
Arithmetic Average:	+ 0.8	+ 0.4	+ 0.8	+ 0.4
Standard Deviation:	0.6	0.9	0.6	0.9
Minimum:	- 0.7	- 1.8	- 0.6	- 1.8
Maximum:	+ 2.4	+ 2.7	+ 2.4	+ 2.7
No. within ± 1 dBA	23	24	23	25
No. within ± 2 dBA	32	32	32	32
Sample Size:	33	33	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 4. Locomotive Straight Track Prediction Differences

Statistical Parameter	*Consultant 1*		*Consultant 2*	
	$L_{Aeq,24hr}$ (dBA)	*L_{Amax} (dBA)*	*$L_{Aeq,24hr}$ (dBA)*	*L_{Amax} (dBA)*
Arithmetic Average:	+ 1.2	+ 0.8	+ 1.2	+ 0.8
Standard Deviation:	0.5	0.6	0.5	0.6
Minimum:	+ 0.6	- 1.0	+ 0.6	- 1.0
Maximum:	+ 2.6	+ 3.2	+ 2.7	+ 3.2
No. within ± 1 dBA	19	26	20	27
No. within ±2 dBA	31	32	32	32
Sample Size:	33	33	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 5. Consist Straight Track Prediction Differences

Statistical Parameter	*Consultant 1*		*Consultant 2*	
	$L_{Aeq,24hr}$ (dBA)	*L_{Amax} (dBA)*	*$L_{Aeq,24hr}$ (dBA)*	*L_{Amax} (dBA)*
Arithmetic Average:	+ 0.8	+ 0.7	+ 0.8	+ 0.7
Standard Deviation:	0.7	0.7	0.6	0.6
Minimum:	- 0.8	- 0.9	- 0.7	- 0.7
Maximum:	+ 2.4	+ 2.2	+ 2.4	+ 2.3
No. within ±1 dBA	23	25	23	26
No. within ±2 dBA	32	32	32	32
Sample Size:	33	33	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Earlier comparison exercises between DOS and Windows-based versions of SoundPLAN identified possible modelling discrepancies in the vicinity of curved track sections. For this reason, curved-track corrections were applied to both the EMU and Consist scenarios to test that the corrections were similarly added in both versions of SoundPLAN.

The resultant prediction differences between SoundPLAN 4.2 and 6.5 were identical to those for the straight track scenarios. As expected, this indicates that the predicted noise levels in both versions were simply increased by the value of the curve correction addition.

No track corrections were modelled for Locomotives, as the wheel/rail interaction is not the dominant noise source for this type of rollingstock.

The results show that generally SoundPLAN 6.5 will give a slightly higher prediction than SoundPLAN 4.2 and is therefore likely to produce a slightly more conservative result than the traditional DOS modelling.

OTHER OUTCOMES

L_{Amax} Source Corrections

The Kilde Report 130 describes two separate components for predicting L_{Amax} noise levels: -

- a point source to represent the locomotive engine; and
- a finite line source to represent the entire train set.

The two components are then added together logarithmically to derive the overall L_{Amax} level. Accordingly, the source input dialogue for the Kilde Report 130 method within SoundPLAN contains two L_{Amax} correction options: –

- an "engine" L_{Amax} (point source); and
- a "wagon" L_{Amax} (finite line source).

An investigation into the predicted noise levels using each of these correction options for a simple straight track section with receivers at 10, 15 and 25 metres was undertaken.

The predicted noise levels indicated that the "engine" L_{Amax} calculated the attenuation with distance as approximately $36 \log_{10}(d_2/d_1)$. In comparison, the "wagon" correction predicted the distance attenuation as $18 \log_{10}(d_2/d_1)$ for a model over flat, hard ground.

It must be noted the formulae contained within Kilde Report 130 are semi-empirical. They were partially derived from rail noise measurements undertaken in Finland. Due to operational and safety constraints there are no QR endorsed rollingstock measurements closer than 25 metres from the source for Queensland rollingstock. Accordingly, it was deemed inappropriate to model rollingstock attenuation levels higher than that of basic acoustic principles (i.e. $20 \log_{10}(d_2/d_1)$ for a point source).

Based on these findings, all modelling for the comparison study has used the "wagon" L_{Amax} correction.

Split Rail Source Strings

During the comparison process, it was discovered that the SoundPLAN 4.2 and SoundPLAN 6.5 implementation of Kilde Report 130 handles split source strings differently when predicting L_{Amax} levels.

When a track is modelled using multiple strings (i.e. source strings that are *not* one continuous source string from start to end) SoundPLAN 6.5 was found to underpredict the L_{Amax} noise levels by up to 2.5 dBA compared to the same section of track modelled using a continuous string. The $L_{Aeq,24hour}$ parameter was not affected.

The SoundPLAN 4.2 implementation did not demonstrate this behaviour and predicted the same L_{Amax} levels for both a continuous and split string. This phenomenon was tested for the extracted section of track [Figure 2] and for a simple straight track section [Figure 3].

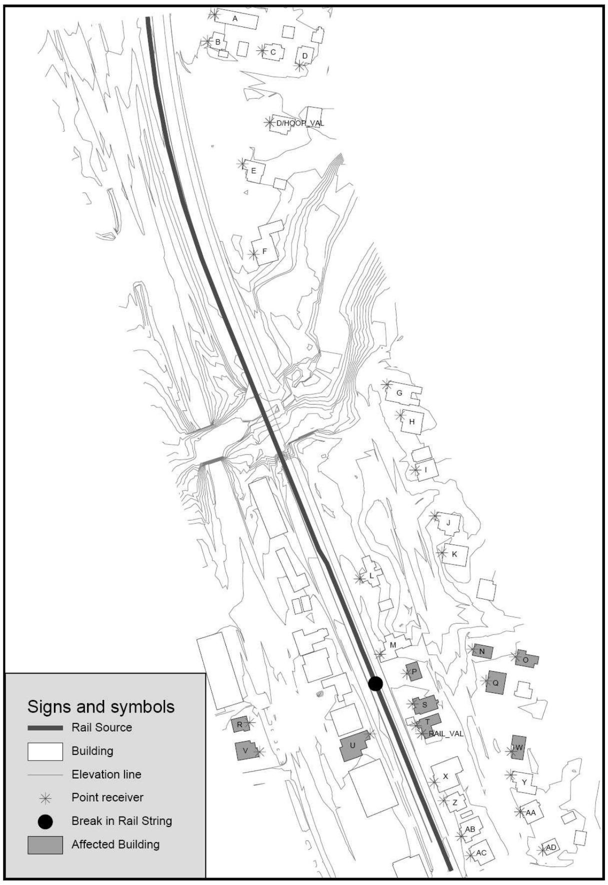

Figure 2. Split Rail Source Line and Receivers Affected by Split String

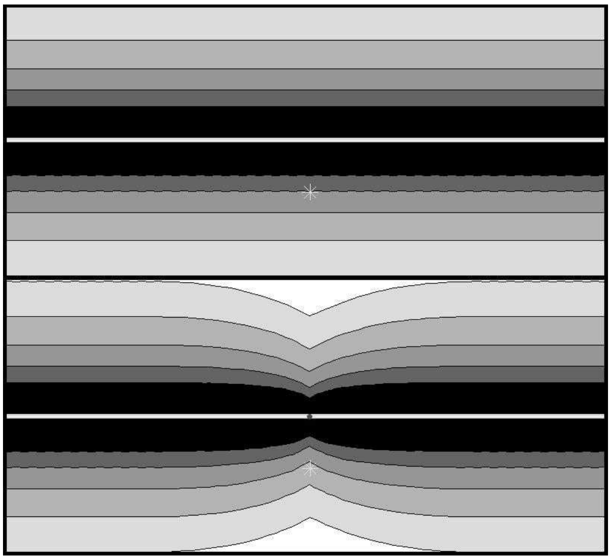

Figure 3. Continuous (Top) and Split (Bottom) Rail Source Lines – SoundPLAN 6.5 - L_{Amax}

It is believed that SoundPLAN 6.5 calculates L_{Amax} levels for each rail string separately and at the start of a new rail string does not include contributions from the full train length. This behaviour was observed using the SoundPLAN animated grid map function.

On this basis, SoundPLAN 6.5 is likely to underpredict L_{Amax} noise levels at a receiver directly adjacent to a split in a rail source line by up to 3 dBA.

Therefore when using the SoundPLAN 6.5 implementation of Kilde Report 130, care must be taken to avoid using split source strings when modelling L_{Amax} noise levels.

Noise Barriers

A comparison of modelled noise levels with the inclusion of a noise barrier was undertaken. A 2.1 metre high noise barrier was added to the straight track test scenario for the EMU and Consist sources in both SoundPLAN 4.2 and 6.5. The barrier was approximately 90 metres long and located at a distance of 6 metres from the rail source line. It provided noise mitigation to 11 receivers.

The predicted attenuation from the barrier for SoundPLAN 4.2 was on average 1.3 dBA higher than the attenuation predicted by SoundPLAN 6.5.

A 4.5 metre high barrier was similarly modelled for the locomotive to ensure that the barrier broke line-of-sight with the elevated source line.

A brief analysis of the prediction differences for the barriers is shown in Tables 6, 7 and 8.

Table 6. EMU Noise Barrier Attenuation Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Arithmetic Average:	+ 1.3	+ 1.3
Standard Deviation:	0.9	0.9
Minimum:	0.0	- 0.1
Maximum:	+ 2.7	+ 2.5
No. within ± 1 dBA	4	4
No. within ± 2 dBA	9	8
Sample Size:	11	11

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 7. Locomotive Noise Barrier Attenuation Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Arithmetic Average:	+ 0.4	+ 0.4
Standard Deviation:	0.4	0.9
Minimum:	- 0.2	- 0.8
Maximum:	+ 1.2	+ 2.1
No. within ± 1 dBA	10	9
No. within ± 2 dBA	11	10
Sample Size:	11	11

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 8. Consist Noise Barrier Attenuation Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Arithmetic Average:	+ 1.4	+ 1.3
Standard Deviation:	0.9	0.9
Minimum:	- 0.1	- 0.1
Maximum:	+ 2.8	+ 2.7
No. within ± 1 dBA	4	4
No. within ± 2 dBA	9	9
Sample Size:	11	11

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Based on prediction differences in Tables 6, 7 and 8, it is concluded SoundPLAN 6.5 produces conservative predictions for barrier attenuation compared to SoundPLAN 4.2.

It is noteworthy that the closest agreement was demonstrated in Table 7 for Locomotive Engines. Locomotive engine noise typically drives noise barrier design heights to achieve Queensland legislative target levels. Therefore this close agreement is a welcome outcome.

Facade Correction and Reflections

As previously discussed facade corrections and reflections are generally handled differently between SoundPLAN 4.2 and 6.5.

To investigate this further the SoundPLAN 6.5 predictions were repeated using reflection calculation settings more similar to those used for the SoundPLAN 4.2 modelling.

A Reflection Order of 10 was selected along with a Reflection Depth of 0. The + 3 dBA facade correction was omitted from the predicted noise levels. Instead, the reflection of the receiver's facade was included to calculate the facade effect.

An analysis of the prediction differences using these settings showed there was typically still one receiver with a prediction difference outside ± 2 dBA. Most of the receivers had prediction differences within ± 1 dBA.

A brief analysis of the prediction differences is shown in Tables 9, 10 and 11 for comparison with the previous results.

Table 9. EMU Straight Track Prediction Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Arithmetic Average:	+ 0.5	+ 0.3
Standard Deviation:	0.6	0.6
Minimum:	-0.1	-0.2
Maximum:	+ 2.2	+ 2.3
No. within ± 1 dBA	29	30
No. within ± 2 dBA	32	32
Sample Size:	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 10. Locomotive Straight Track Prediction Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Average:	+ 0.4	+ 0.2
Standard Deviation:	0.6	0.6
Minimum:	-0.3	-1.5
Maximum:	+ 2.0	+ 2.7
No. within ± 1 dBA	28	31
No. within ± 2 dBA	33	32
Sample Size:	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Table 11. Consist Straight Track Prediction Differences

Statistical Parameter	$L_{Aeq,24hr}$ *(dBA)*	L_{Amax} *(dBA)*
Average:	+ 0.5	+ 0.4
Standard Deviation:	0.6	0.6
Minimum:	-0.1	-0.2
Maximum:	+ 2.1	+ 2.0
No. within ±1 dBA	30	30
No. within ±2 dBA	32	32
Sample Size:	33	33

Note: Average, Standard Deviation, Minimum and Maximum in dBA. A positive value indicates SoundPLAN 6.5 prediction higher than SoundPLAN 4.2.

Using this methodology, more receivers were found have a prediction difference within ± 1 dBA of the results predicted by SoundPLAN 4.2.

Search Radius Selection

SoundPLAN 4.2 does not have an option to adjust the search radius for its calculations.

For the comparison study, the search radius within SoundPLAN 6.5 was set to 500 metres. The primary reason for this choice of search radius is that the Kilde Report 130 methodology states it is only valid up to 300 metres from a rail source. The default search radius within SoundPLAN 6.5 is 5,000 metres; therefore an investigation was completed to test the influence of this calculation parameter on the prediction results.

The predicted SoundPLAN 6.5 noise levels were very similar for both a 500 metres and 5,000 metres search radius.

Table 12 summarises the number of receivers for which predicted noise levels differed for different search radii. In all cases, the prediction difference was 0.3 dBA or less.

Table 12. Receivers with Prediction Difference >0 dBA

Noise Parameter	*No. of Receivers*		
	EMU	*Loco*	*Consist*
$L_{Aeq,24hr}$	4	2	6
L_{Amax}	0	0	5

It should be reiterated, however, the test section is only 600 metres in length. Therefore, these results are not conclusive.

When comparing a search radius of 1,000 metres to 5000 metres, identical prediction differences were calculated in all cases. Therefore, it is possible the magnitude of the prediction differences has been limited in this instance by the small test section size. The prediction differences may be larger for a full rail noise model of greater length.

CONCLUSIONS

From this study it was found that the implementation of the Kilde Report 130 in SoundPLAN 6.5 produces very similar results to that of the current QR-accepted method of modelling, SoundPLAN 4.2.

It was found that SoundPLAN 6.5 predicts slightly higher noise levels than SoundPLAN 4.2. All but one of the 33 receivers had a prediction difference within ± 2 dBA.

This study also highlighted areas requiring caution when using the SoundPLAN 6.5 implementation of the Kilde Report 130 method. In particular, issues were identified in relation to the locomotive engine correction and split source strings.

It was also identified that the noise barrier attenuation in SoundPLAN 6.5 was generally more conservative than SoundPLAN 4.2.

Overall no impediment was found to prevent the use of the Kilde Report 130 as implemented in SoundPLAN 6.5 for rail noise prediction within Queensland.

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