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Comparison of Kilde and NORD2000 rail noise prediction methodologies

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ABSTRACT

In Australia, predictions of rail noise are most commonly conducted using the Kilde Rep 130 methodology, which has been twice superseded. The most recent version of the Nordic methodology is NORD2000. This paper compares the practical results of the Kilde and NORD2000 methodologies in a range of simple scenarios which have been selected to isolate specific effects, such as source directivity, meteorological effects, shielding losses and reflections. A test case representing complex real-world conditions has also been studied.

Significant differences have been observed in the results of the two methodologies, with NORD2000 generally predicting larger propagation losses. Determining which methodology provides more accurate predictions would require comprehensive measurements in tightly controlled conditions. However, it appears that Kilde uses a more conservative approach, to provide 'margin for error' due to its simplistic calculations.

Keywords: Rail, Kilde, Nord2000 I-INCE Classification of Subjects Number(s): 13.4.1, 76.1.2

1. INTRODUCTION

In Australia, predictions of rail noise are most commonly conducted using the Kilde Rep 130 methodology. The Kilde methodology has been superseded, originally by the Nordic Prediction Method (NMT 96) and then by NORD2000. While the Kilde methodology was designed for implementation using hand calculations, NORD2000 is designed for computer implementation. Therefore NORD2000 uses more sophisticated techniques in its propagation model, such as

- split height source modeling
- ground effect based on Fresnel zones
- inclusion of meteorological effects
- 1/3 octave band assessment

While there are many rail noise prediction methodologies available, for example CRN in the UK, the assessment of maximum pass-by (L_{max}) rail noise levels is required by rail noise policies in New South Wales, Victoria and Queensland. Kilde and NORD2000 are amongst the few methodologies which allow the L_{max} noise levels to be calculated.

CNOSSOS-EU is a prediction methodology which is currently in development and may someday supersede NORD2000. However, it is currently scheduled for release in 2015 and does not include the calculation of L_{max} noise levels (1).

Since NORD2000 is the latest evolution of the Kilde methodology, it has the potential to be used for rail noise assessments in Australia. The purpose of this paper is to identify the practical differences in propagation calculations between Kilde and NORD2000 that would need to considered and understood if there was to be a wide-scale shift to the use of NORD2000.

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2. METHODOLOGY

In order to demonstrate the key differences between the Kilde and NORD2000 methodologies simple test scenarios were implemented in SoundPLAN 7.3. The calculation settings used were 500 m search radius, reflection order 1, tolerance 0.1 dB.

The railway source levels are based on measurements of diesel multiple units (DMUs) in Victoria. The source level was calculated using a straight line model to reflect the conditions of the measurement location, which were:

- source length 600 m
- L_{max} source classified as wagons (to represent the distributed source of a DMU)
- ground factor 0.6 (Kilde)
- ground resistivity 80 kNs/m^4 (NORD2000)
- ground roughness class 0.5 (NORD2000)

Neither prediction methodology includes Australian trains in its source library. The source levels were calibrated based on a measured sound exposure level (SEL) of 95.0 dB(A) and L_{max} of 91.4 dB(A) at a distance of 15 metres. NORD2000 requires source spectra, these spectra are based on the measured levels and shown in Figure 1.

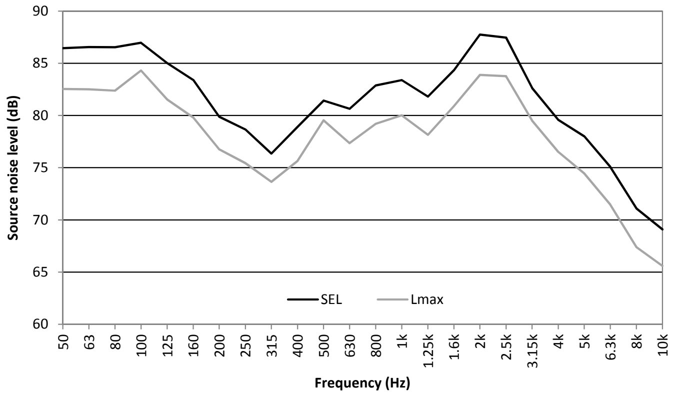


Figure 1: Railway source level spectrum

3. Source directivity

While the source levels are user-adjustable, the source directivity is set by the prediction methodology. Cross-sections of the Kilde and NORD2000 sources have been created, in order to compare the source directivities.

Figure 2 and Figure 3 show that Kilde uses an onmi-directional source, resulting in higher predicted noise levels than NORD2000 for elevated receivers. NORD2000 is likely to better represent the source directivity where wheel-rail noise is dominant. However where the dominant noise source is on top of the train (eg engine or exhaust), NORD2000 may under-predict noise levels for receivers looking over the railway line (eg houses at the edge top of a steep cutting)

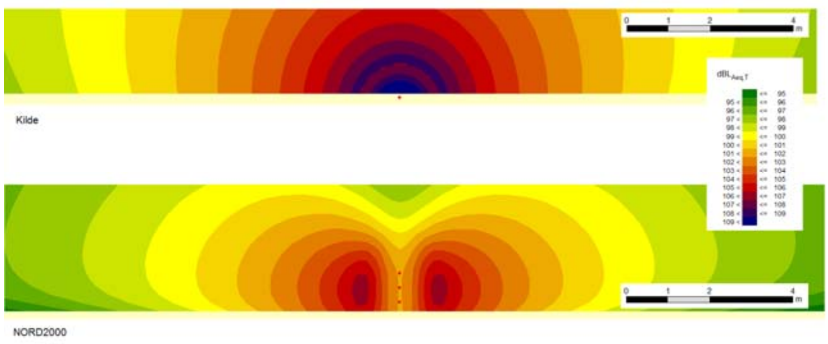


Figure 2: Cross-section of SEL sources

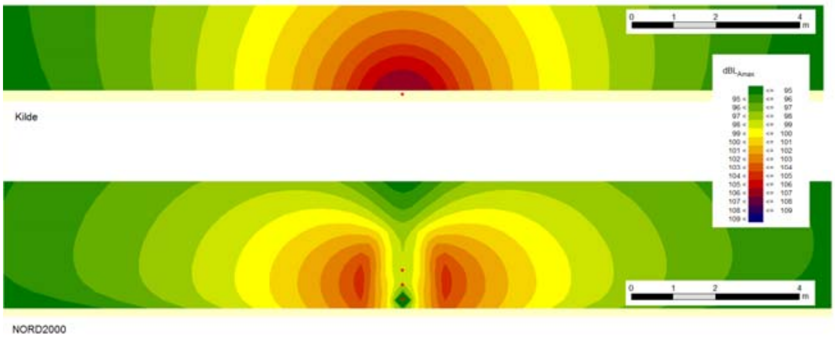


Figure 3: Cross-section of L_{max} sources

4. Basic propagation

Cross-sections have been created of noise levels for a single train passby on an infinite length straight-line rail source propagating over soft ground. To provide a height scale, black dots represent ground and first floor receivers at heights of 1.5 and 4.5 metres. It should be noted that the source levels were calibrated based on measurements at 15 metres from the source, as described in the Methodology section.

Figure 4 shows that NORD2000 adopts a larger ground effect, particularly for L_{max}. This results in lower predicted noise levels close to the ground for NORD2000. Since receivers are usually close to the ground, this results in NORD2000 having greater propagation losses than Kilde as distance increases. It is also worth noting the NORD2000 is much more sensitive to receiver elevation for receivers close to the ground, particularly at propagation distances under 200 metres.

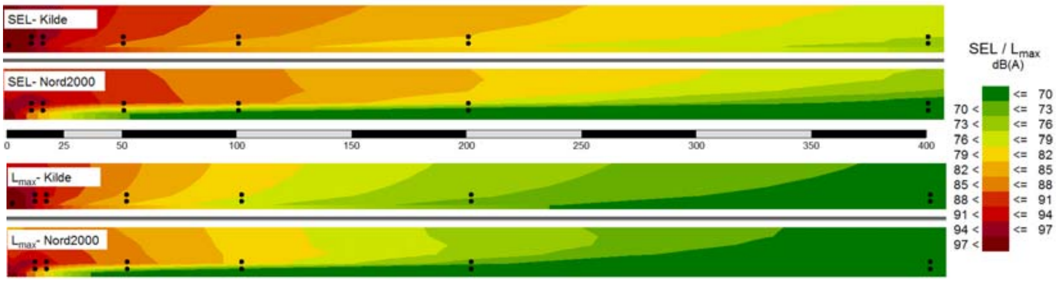


Figure 4: Cross-section showing horizontal propagation

5. Ground effect

The above comparison is repeated for hard ground. Since the SEL and L_{max} showed the same trends previously, only SEL is investigated further. As shown in Figure 5, a reflective ground has reduced the difference between Kilde and NORD2000. It remains that NORD2000 adopts marginally greater propagation loss.

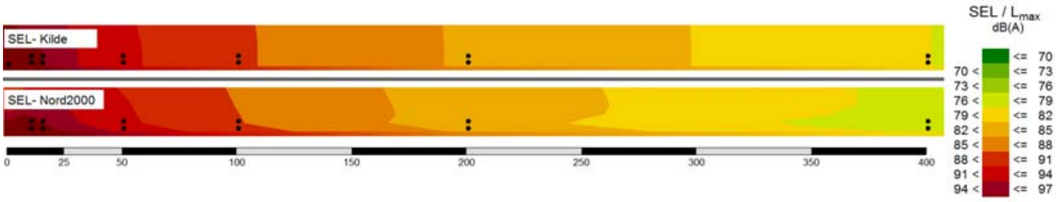


Figure 5: Cross-section showing hard ground propagation

Ground roughness can be varied in NORD2000 but not Kilde. All previous results are based on a ground roughness chosen to best represent typical measurement conditions. Reducing the roughness tends to reduce the difference between Kilde and NORD2000. Horizontal noise contours have been created (calculated 1.5 metres above ground level) to compare propagation losses over hard (Figure 6) and soft ground (Figure 7) with NORD2000 roughness set to zero (NORD2000 contours shown solid, Kilde contours shown dashed) . Source levels have been recalibrated for the changed ground conditions.

For hard ground, based on the SEL, NORD2000 has greater propagation losses than Kilde, even at the minimum NORD2000 roughness. For the L_{max} over hard ground, NORD2000 is similar to Kilde at the minimum NORD2000 roughness.

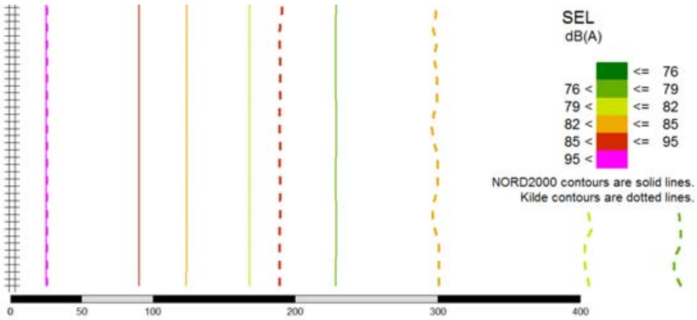


Figure 6: Noise contours with NORD2000 roughness set to zero- SEL over hard ground

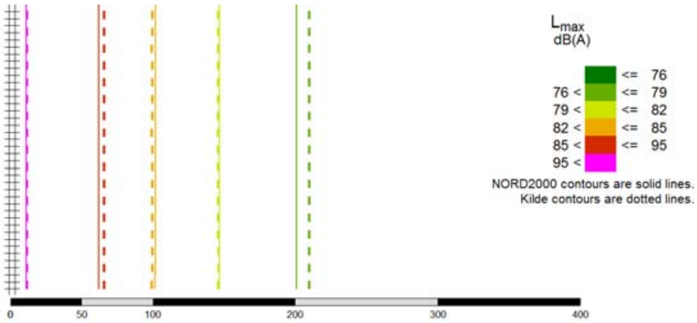


Figure 7: Noise contours with NORD2000 roughness set to zero- L_{max} over hard ground

For soft ground, the closest correlation to Kilde soft ground was found using the following NORD2000 settings: zero roughness, hard ground, corrections of -2 dB (SEL) and -3 dB (L_{max}). These settings surprisingly provided a better correlation than any combination of settings using soft ground. The comparisons are shown in Figure 8 and Figure 9.

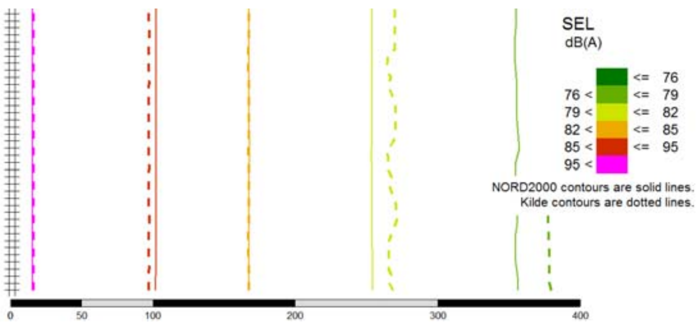


Figure 8: Noise contours with NORD2000 roughness set to zero- SEL over soft ground

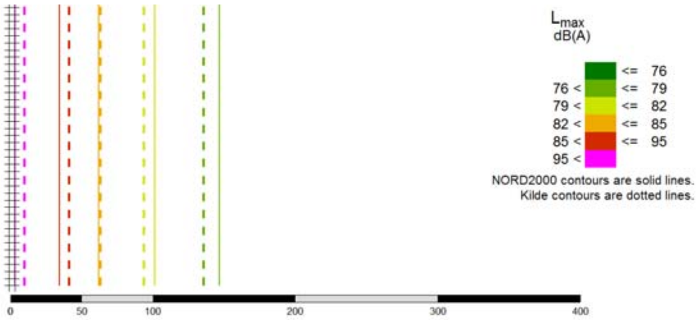


Figure 9: Noise contours with NORD2000 roughness set to zero- L_{max} over soft ground

It should be noted that these results apply only for flat ground propagation. Due to the directivity effects shown earlier, differences in elevation will change the propagation losses for Kilde and NORD2000.

6. Terrain gradient

To investigate the effects of sloping terrain, a 50% gradient was modelled. The ground absorption was calibrated so that the Kilde and NORD2000 methodologies predicted the same noise levels over flat ground. Figure 10 shows that NORD2000 has increased propagation losses due to sloping terrain than Kilde.

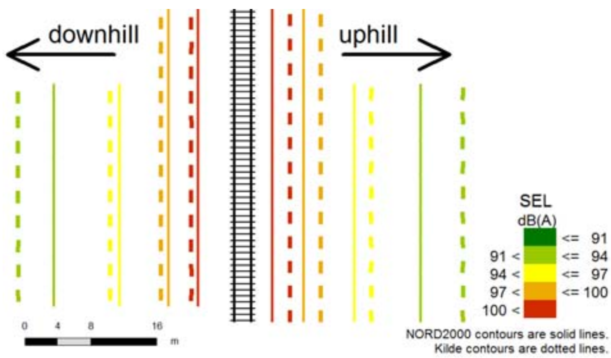


Figure 10: Noise contours for sloped terrain

7. Meteorological effects

All results above are based on neutral weather conditions in NORD2000. Kilde does not include weather effects. Figure 2 and Figure 3 show that NORD2000 has higher propagation losses under neutral weather conditions.

Calibration of straight line propagation loss based on wind speed has been investigated. All other parameters were set according to the values in the Methodology section, including ground roughness class 0.5. The closest correlation of Kilde propagation losses in NORD2000 occurs at upwind speeds of 0.5 m/s for SEL and 0.2 m/s for L_{max}. The L_{max} correlation cannot be matched for all distances, so in this case the 50-100 metre range was given priority. The comparisons are shown in Figure 11 and Figure 12. For reference, the NORD2000 neutral weather case is shown below the length scale.

It should be noted that this correlation based on weather conditions would be affected by changes to ground resistivity, ground roughness, train length, source elevation and receiver elevation.

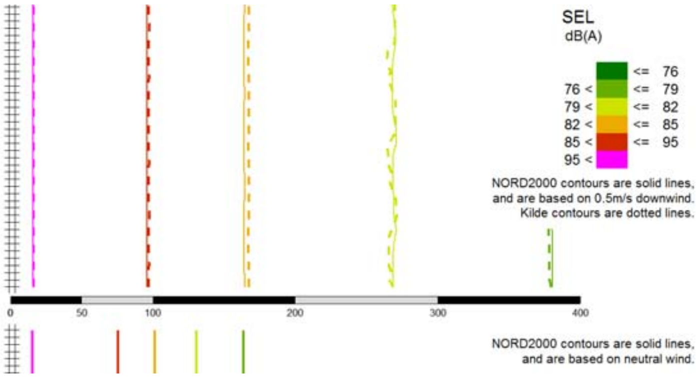


Figure 11: Noise contours for NORD2000 calibrated to Kilde using wind speed- SEL

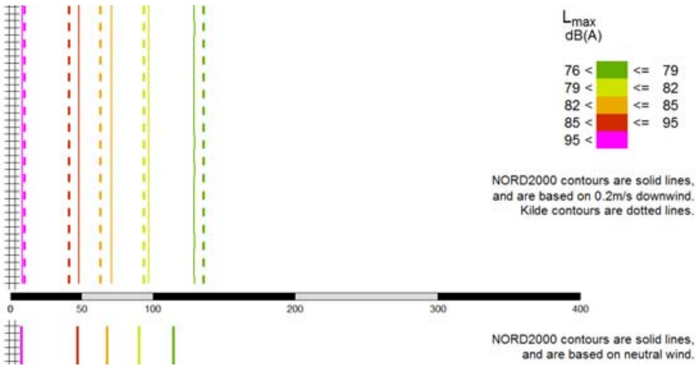


Figure 12: Noise contours for NORD2000 calibrated to Kilde using wind speed - L_{max}

To illustrate the effect of wind speed, results have been produced for upwind and downwind, at speeds of 2 m/s and 4 m/s. Figure 13 shows that NORD2000 is very sensitive to wind speed. It is noted that the wind speeds investigated are relatively low; on the Beaufort scale, 2 m/s corresponds to a light breeze and 4 m/s corresponds to a gentle breeze.

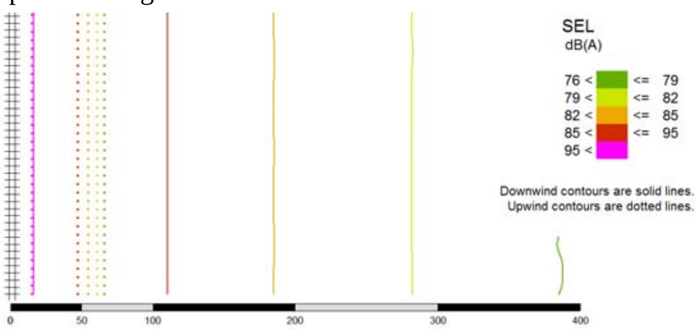


Figure 13: Wind effects in NORD2000 for 2 m/s

Figure 14 shows that increasing the NORD2000 wind speed from 2 m/s to 4 m/s results in slightly lower predicted levels for the upwind case, and no noticeable difference for the downwind case.

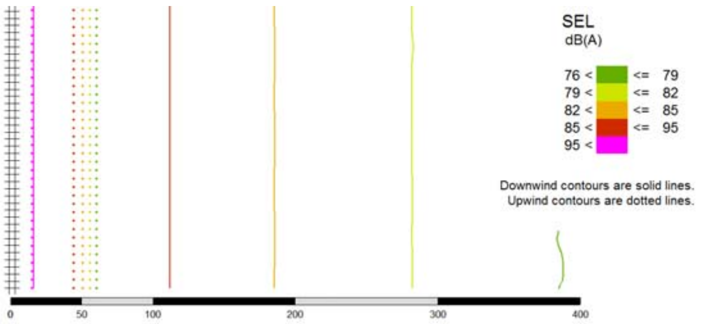


Figure 14: Wind effects in NORD2000 for 4 m/s

8. Shielding from barriers

The shielding effects of barrier heights up to 4 metres have been investigated and are shown in Figure 15 to Figure 17. The results are shown are for SEL, since the L_{max} results followed the same trends. To provide a scale for height, black dots show example ground floor and first floor receivers. Barrier losses are higher in NORD2000 than Kilde.

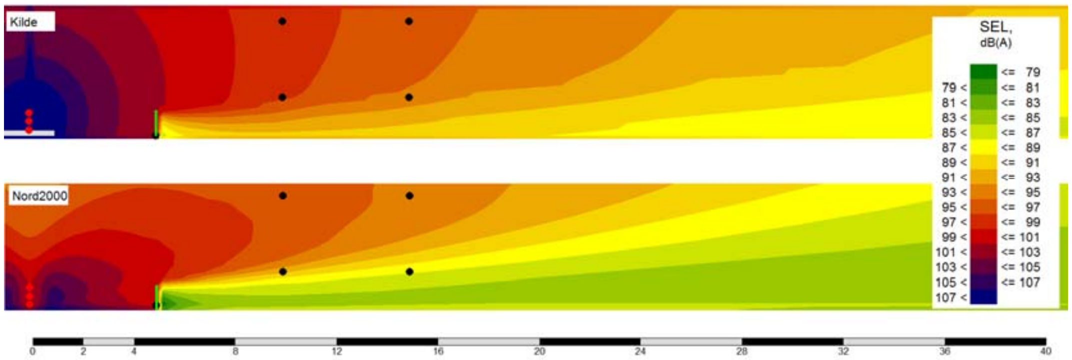


Figure 15: Cross-section for 1 metre high noise wall

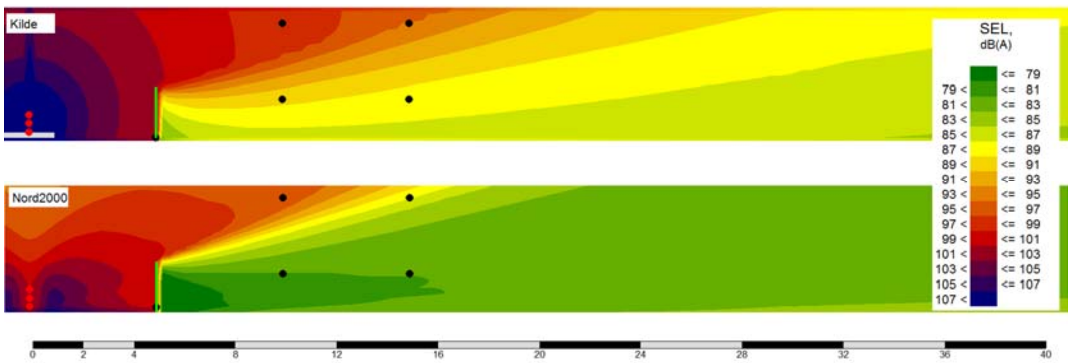


Figure 16: Cross-section for 2 metre high noise wall

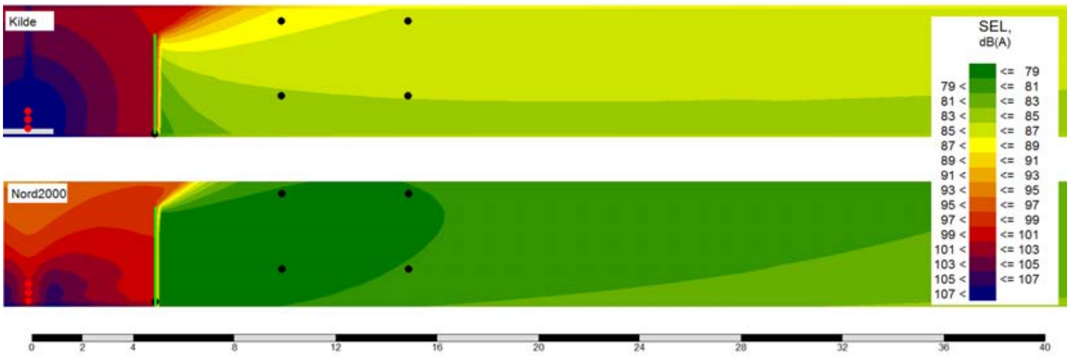


Figure 17: Cross-section for 4 metre high noise wall

9. Shielding from cuttings

In order to compare the loss from cuttings, it has been necessary to increase the NORD2000 source level to compensate for the differences in source directivity between Kilde and NORD2000. Figure 18 that the shielding loss due to a cutting is similar for Kilde and NORD2000. However, in practice, NORD2000 will predict lower due to the source directivity shown in Figure 2.

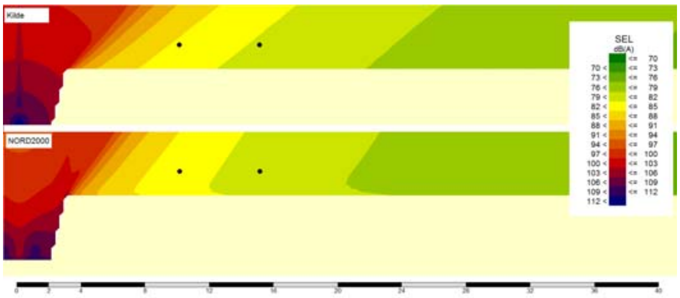


Figure 18: Cross-section for 4 metre deep cutting

10. Shielding from buildings

As shown in Figure 19, NORD2000 predicts higher losses for building shielding than NORD2000.

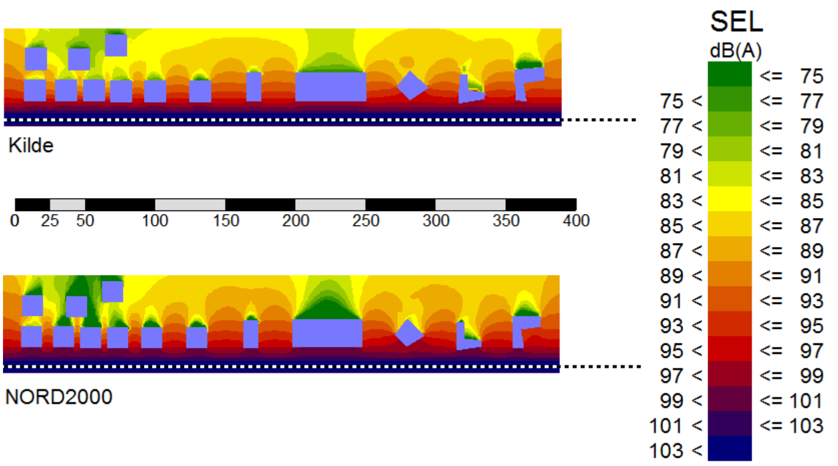


Figure 19: Noise contours with shielding due to buildings

11. Combination of effects

The examples below show the overall effects for example real-world topography, using neutral weather conditions.

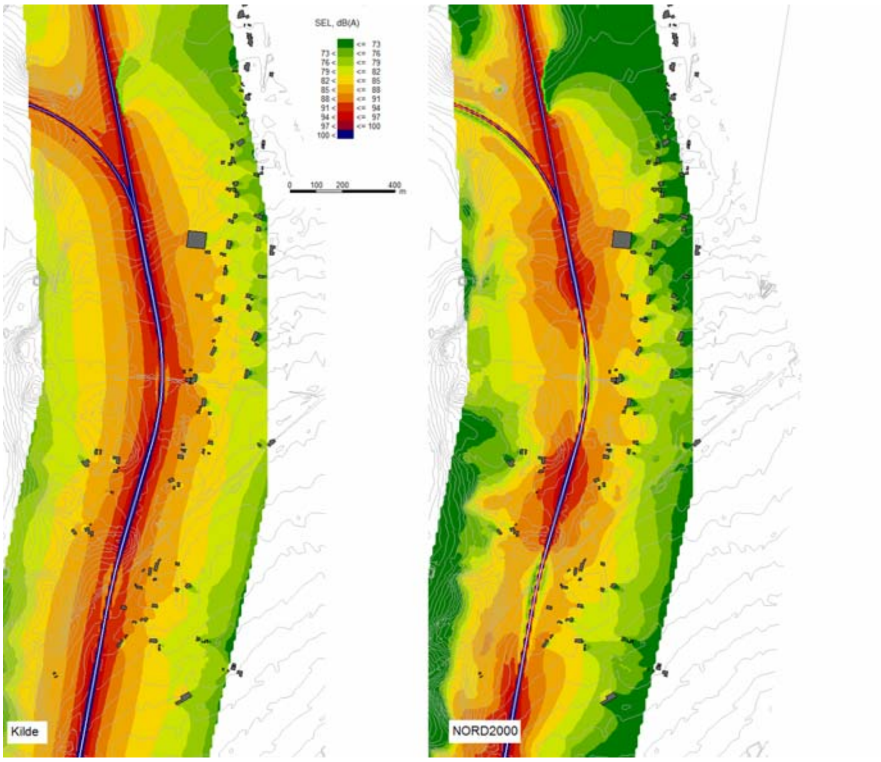


Figure 20: Noise contours for example real-world topography- SEL

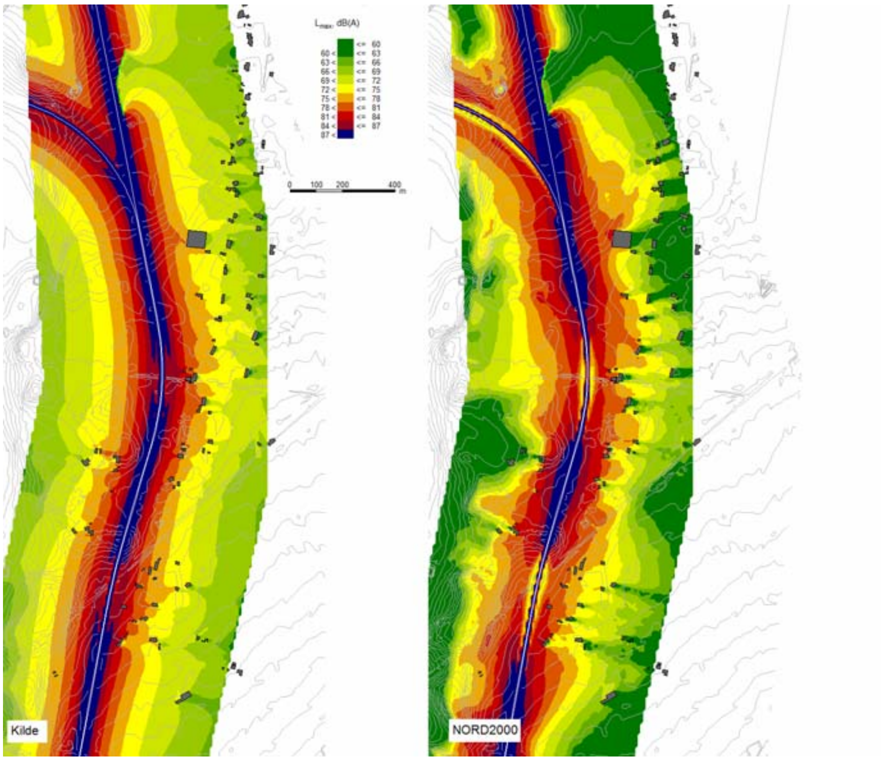
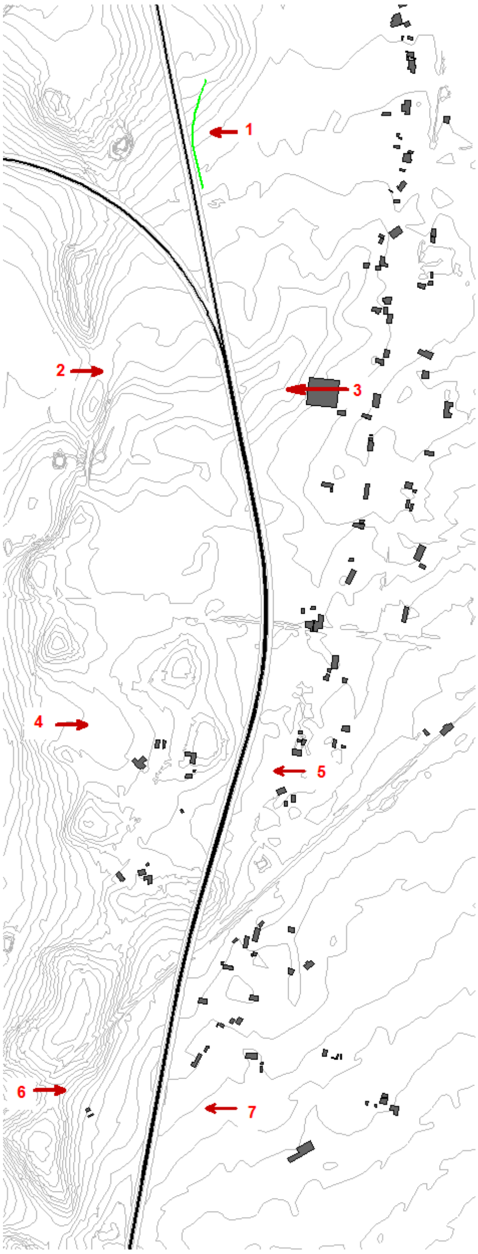


Figure 21: Noise contours for example real-world topography- L_{max}

A discussion of expected causes for differences is shown in Figure 22. The general trend, especially at distances greater than 400 metres, is for NORD2000 to predict lower noise levels than Kilde. This is due to the greater spreading and ground effect losses in NORD2000.



1. Higher barrier loss in NORD2000
2. Lower propagation loss in NORD2000 on the side of hill facing the railway
3. Higher façade reflection addition in NORD2000
4. Higher propagation loss for receivers partially shielded by terrain in NORD2000
5. Lower propagation loss for unshielded receivers across flat ground in NORD2000
6. Greater effect of terrain and building shielding in NORD2000, causing more variation in noise contours.
7. Band of raised noise levels in NORD2000, due to elevated rail and source directivity

Figure 22: Comparison based on example real-world topography

12. CONCLUSIONS

Significant differences have been observed in the results of the two methodologies, with NORD2000 generally predicting larger propagation losses. Determining which methodology provides more accurate predictions would require comprehensive measurements in tightly controlled conditions. However, it appears that in general Kilde uses a more conservative approach, to provide 'margin for error' due to its simplistic calculations.

REFERENCES

1. Kephalopoulos S, Paviotti M, Anfosso-Lédée M. Common Noise Assessment Methods in Europe (CNOSSOS - EU). Luxembourg: Publications Office of the European Union; 2012. p. 27