inter.noise
21-24 AUGUST
SCOTTISH EVENT CAMPUS
GLASGOW 2022

Impact of Ground Cover Selection on CNOSSOS-EU Calculated Levels

Chris Youdale[1], James Trow[2]
Noise Consultants Ltd
6 Bankside, Crosfield Street, Warrington, WA1 1UD

Simon Shilton[3]
Acustica
3000 Aviator Way, Manchester, M22 5TG

ABSTRACT

The influence of ground absorption on calculations using the CRTN 1988[1] and CRN 1995[2] methodologies has been researched and is well understood. For previous rounds of strategic mapping, this has led to the recommendation of adopting CORINE Land Cover[3] data which can be used to allocate appropriate ground absorption coefficients to represent the acoustic absorptivity or reflectivity of the ground surfaces that the dataset describes. However, there has been no equivalent studies into how the selection of a ground cover dataset may influence calculated noise levels using the CNOSSOS-EU[4] methodology. Therefore, to support Round 4 of the strategic mapping, an investigation into the effect of ground cover selection on CNOSSOS-EU calculated levels and calculation times was undertaken. Test models were developed incorporating prepared ground cover datasets based on CORINE Land Cover 2018, CEH Land Cover Map 2019[5] and OS Mastermap Topography Layer[6], (a 'low', 'medium' and 'high' resolution dataset respectively) and used to perform noise calculations across a rural and urban/suburban propagation environment using the CNOSSOS-EU methodology. Comparison between the results of all models indicated that the medium resolution dataset offered the best compromise between introducing a low level of uncertainty in the calculated noise levels and improved calculation time for national coverage noise mapping.

1. INTRODUCTION

The UK's Department for Food and Rural Affairs (Defra) commissioned a series of studies investigating the sensitivity of the CNOSSOS-EU noise assessment method. These studies were commissioned to support data governance, and aimed to quantify aspects of potential uncertainty in Defra's national noise model. One such study was to investigate the impact of ground cover selection on CNOSSOS-EU calculated noise levels.

Ground effects are considered in environmental noise models by defined areas or regions of 'ground cover'. These are typically depicted by 2D polygon objects where the type of surface, e.g.

---

[1] chrisyoudale@noiseconsultants.co.uk

[2] jamestrow@noiseconsultants.co.uk

[3] Simon.Shilton@acustica.co.uk

water, grassland or hard standing, is allocated a coefficient to represent its acoustic absorption/reflection/scattering. The detail to which ground cover is represented in a noise model is determined by the spatial resolution of the selected input dataset, and the degree to which attribution can be used to assign acoustic coefficients. In general, the lower the resolution that ground cover objects are represented, the greater the uncertainty that will exist within calculated noise levels. However, as low-resolution datasets will simplify the modelled sound propagation, the use of such objects have the potential to reduce model processing and calculation times. A study was therefore undertaken to review, consider and recommend approaches to modelling ground cover for use within the CNOSSOS-EU calculation method.

2. CONTEXT

2.1. CNOSSOS-EU Method Overview

The CNOSSOS-EU method consists of three distinct modelling parts: The source model (which describes how to model noise emission due to road, rail, industrial and aircraft); the propagation model (derived from the NMPB 2008[7] model for road, rail and industry sources and for aircraft sources based on the ECAC Doc29 4th Edition[8] model); and the receiver model (which specifies how receiver grids and façade points are to be defined, and how to attribute the number of dwellings, and people in dwellings, in residential buildings, to calculated façade L_{den} and L_{night} noise levels). Ground effects are considered within the calculation of propagation for road, railway and industrial sources.

2.2. Assignment of Ground Absorption Factors (G) to Areas of Ground Cover

The CNOSSOS-EU propagation model includes ground cover effects both during free propagation and in the presence of diffraction, where the ground effects are considered on both the source side and receiver side of the diffraction point. The ground cover effects are defined by a ground factor ‘G’, which is a value between 0 and 1, (where 1 represents acoustically soft absorptive surfaces and 0 represents acoustically hard reflective surfaces).

Table 2.5.a of CNOSSOS-EU defines ground factors for eight classes of ground surface. The values in Table 2.5.a are defined by Directive 2015/996[9] (as amended by Directive 2021/1226[10]), therefore it is a legal requirement to consider them when assigning appropriate values of ‘G’ to areas of ground cover. Additionally, it is specified that $G = 0$ for road platforms (note: The absorption of porous road pavements is taken into account in the emission model), slab tracks, and $G = 1$ for rail tracks on ballast. Table 2.5.a includes the assignment of $G = 0$ to hard surfaces (e.g. asphalt, concrete, water), however the RIVM Letter report 2019-0023[11] identifies an issue in the CNOSSOS-EU method in which a discontinuity in the results occurs in instances where all ground along the source to receiver path has $G = 0$. The working group associated with the report did not manage to resolve this issue through amendments to the ground attenuation model, therefore it recommended that $G = 0$ is redefined as $G = 0.0001$ to avoid this discontinuity.

Whilst it was necessary to consider the values of G presented in Table 2.5.a of CNOSSOS-EU, it was deemed necessary to provide some minor additions to the descriptions and values in the table for the purposes of improving clarity, and/or helping to ease alignment with available ground cover datasets, informed by a literature review of other guidance and resources.

The IMAGINE project[12] commenced in November 2003 and aimed to extend the Harmonoise rail and road source databases, as well as develop aircraft and industrial noise source calculation methods. IMAGINE Work Package 1 (WP1) provides “practical guidelines for data management and information technology aspects of noise mapping” which includes consideration of ground cover. This includes the assignment of $G = 0.75$ for “semi-urban, open housing, mixed ground”.

The Finnish Transport Agency (Liikenneviraston) instructions "CNOSSOS-EU calculation model – Calculation settings and model principles"[13], specifically assigns G = 0 to "the area below buildings" i.e.: building footprints. This is consistent with the approach taken within many noise calculation software systems; therefore, it was recommended to add this to the table to improve transparency.

WG-AEN GPG v2[14] recommends Toolkit 13 is used to determine ground surface type, which provides tools to apply ground coefficients to land use types. It includes an entry for G = 0.5 as "Residential".

The literature review did not identify any studies investigating the uncertainty introduced by adopting an inappropriate G coefficient value for ground cover in the context of CNOSSOS-EU.

In view of the literature reviewed and discussion above, Table 1 below sets out the recommended table of G values to be used in Defra's implementation of CNOSSOS-EU. It is based upon the tables and text within CNOSSOS-EU, and extended from other guidance where noted.

Table 1: Recommended G Values for Different Types of Ground

Description	**G Value**
Very soft/snow or moss-like	1
Soft forest floor/short/dense heather-like or thick moss	1
Uncompacted, loose ground/turf/grass/loose soil railway ballast[1]	1
Normal uncompacted ground/forest floors/pasture field	1
Compacted field and gravel/compacted lawns/park area/semi-urban, open housing, mixed ground[2]	0.7
Residential i.e.: mixed urban areas[3]	0.5
Compacted dense ground/gravel road/car park/dense urban landscape, mostly mineralised surfaces[2]	0.3
Hard surfaces/most normal asphalt i.e.: road surfaces[4]/light rail on slab track[5]/buildings[6]/concrete	0.0001[7]
Very hard and dense surfaces/dense asphalt/concrete/water	0.0001[7]

Notes:

[1] Directive 2015/996
[2] IMAGINE default values
[3] WG-AEN GPG v2 Toolkit 13
[4] Directive 2015/996
[5] Directive 2015/996
[6] Finnish Transport Agency instructions 4/2017
[7] RIVM 2019

3. METHODOLOGY

3.1 Options for Modelling Ground Cover

In support of developing Defra's noise model, three datasets were identified for consideration, and for the purposes of the study were categorized as 'low', 'medium' and 'high' resolution datasets: CORINE Land cover 2018 (CLC 2018) – a low resolution dataset; CEH Land Cover Map 2019 (LCM

2019) – a medium resolution dataset; and OS Mastermap Topography Layer (OSMM Topo) – a high resolution dataset that is perpetually updated by Ordnance Survey every 6 weeks.

3.2 Preparation of Acoustic Test Areas

Two modelled test areas within the Manchester locality (each comprising an area of 25 km^2) were selected for testing, having regard for different propagation characteristics (i.e. where ground cover characteristics are likely to vary), namely: Urban locations – where ground cover was expected to consist of lower G values representing more reflective surfaces; suburban locations – where ground cover was expected to include a mixture of G values i.e. reflective and absorbing surfaces, and intervening values; and rural locations – where ground cover was expected to predominantly consist of softer absorptive ground surfaces. A description of the test areas utilized in this study are summarised in Table 2.

Table 2: Study Acoustic Test Areas

Area	Description
1	A rural environment split almost centrally by a motorway running north to south. Ground cover in this area is noted to predominantly consist of “acoustically soft” ground (G = 1). The area includes a lot of open space, however there are also small residential settlements and small areas of industrial uses.
2	An area characterised predominantly by urban and suburban environments. Ground cover in this area is noted to consist of far less “acoustically soft” (G = 1) ground in comparison to Area 1. Area 2 is also more built-up, where it is densely populated by residential dwellings and large industrialised areas, therefore there is far less open space in Area 2 when compared to Area 1.

3.3 Model Setup

A 3D noise model was developed using GIS and feature manipulation tools within the areas described in Table 2 above. Since the CNOSSOS-EU method considers ground effects only within the propagation part of its model, and the propagation part of the model is the same for road, rail and industrial sources, only road traffic noise sources were included in the model. Each model used the exact same input data with the exception of the ground cover datasets.

Grid calculations for the L_{day}, L_{eve}, L_{night} and L_{den} noise metrics were undertaken at 10m intervals. The model settings were standardised across all models to ensure that the only differences in results would be as a result of the ground cover datasets used in the model.

3.4 Preparation of Ground Cover Datasets

Each of the ground cover datasets considered in the testing are represented as a series of polygon objects that include attributes identifying the type of ground cover that the polygon represents. Whilst the format of the data is consistent (they are all polygon objects), the way in which each dataset has been attributed is not. Therefore, an exercise was undertaken to assign the recommended values of G (Table 1) to each ground cover dataset, having regard for the description provided for each land class of the dataset supported by a review of the datasets against aerial imagery.

The CLC 2018 and LCM 2019 ground cover datasets did not account for road surfaces or rail ballast. In order for them to include these areas, they were extracted from the OSMM Topo dataset and intersected into the CLC 2018 and LCM 2019 ground cover datasets.

4. RESULTS

4.1 Test Scenarios

The OSMM Topo data is the most detailed and up-to-date dataset of the three ground cover datasets included in this study, consequently it is considered to be the most representative of the "real-world" situation. However, due to the complexity of the dataset it may result in increased calculation time, when compared to less complex ground cover datasets. The objective of the test calculations for the two areas of interest, for the three different ground cover datasets, was to assess how the change in ground cover dataset affected both calculation time and results, in comparison to the OSMM Topo base case. The results of the analysis would then determine whether the CLC 2018 or LCM 2019 ground cover datasets would provide a reduction in calculation time whilst preserving the noise level results within acceptable margins. The test scenarios analysed for this purpose are summarised in Table 3.

Table 3: Test Scenarios

Scenario	Description
CLC 2018 vs OSMM Topo	A comparison of model results where the ground cover model objects are based upon the processed CLC 2018 data against the model results where the ground cover model objects are based upon the OSMM Topo data (the benchmark model).
LCM 2019 vs OSMM Topo	A comparison of model results where the ground cover model objects are based upon the processed LCM 2019 data against the model results where the ground cover model objects are based upon the OSMM Topo data (the benchmark model).

4.2 CNOSSOS-EU Quality Criteria

The CNOSSOS-EU:2020 method includes a quality framework in section 2.1.2. It includes the following on the accuracy of input values: *"All input values affecting the emission level of a source shall be determined with at least the accuracy corresponding to an uncertainty of ± 2 dB(A) in the emission level of the source (leaving all other parameters unchanged)."*

This defines an acceptable range of uncertainty in the emission sound power level due to the influence of any specific uncertainty in the input values. Ground cover selection relates to the propagation aspects of calculating noise levels. As such, the quality framework does not apply. However, a criterion of ± 2 dB(A) may be considered to provide a useful indicator when comparing the impact of data selection decisions.

Whilst the ± 2 dB(A) range appears specific, it is open to interpretation in a number of ways, therefore the statistical comparisons made in this study have followed a number of approaches:

- A Standard Deviation (SD) of 1.0 dB(A) or less would indicate that 95% of the samples would be within ± 2 dB(A) of the mean, (assuming a normal distribution of samples about the mean);
- A Coverage Interval (CI) of 4.0 dB(A) or less would indicate that 95% of the samples would be within ± 2 dB(A) of the mean;
- A $q_{0,1}$ to $q_{0,9}$ range of 4.0 dB(A) or less would indicate that 80% of the samples would be within ± 2 dB(A); and
- A Range of 4.0 dB(A) or less would indicate that 100% of the samples would be within ± 2 dB(A).

The mean difference is also presented as it provides an indication of whether a statistical bias is introduced into the results, such as a tendency for an overall shift towards higher or lower results.

4.3 Summary of Results

Table 4 presents a summary of the statistical analysis performed on the calculated result grids across all calculated noise metrics (L_{day}, L_{eve}, L_{night} and L_{den}), hence some results are presented as a range. Where only a single value is presented it means that the same result occurred across all noise metrics.

Table 4: Summary of Statistical Analysis

Scenario	**Area**	**Mean Difference (dB)**	**Standard Deviation (dB)**	**95% Coverage Interval (dB)**	**$q_{0,1}$ to $q_{0,2}$ Range (dB)**	**Range (dB)**	**Calculation Time (% w.r.t OSMM Topo)**
CLC 2018 vs OSMM Topo	1	0.0	0.7 to 0.9	3.4 to 3.8	1.2	12.4 to 13.1	40
LCM 2019 vs OSMM Topo	1	-0.2 to -0.1	0.4	1.8 to 1.9	0.6	10.3 to 10.7	49
CLC 2018 vs OSMM Topo	2	0.2	0.4 to 0.5	1.9 to 2.0	0.9	7.2 to 7.5	30
LCM 2019 vs OSMM Topo	2	-0.1 to 0.0	0.5	2.0 to 2.1	1.1	9.1 to 9.9	38

To supplement the analysis, difference grids calculated from the results grids output by the models across all calculated noise metrics were produced and reviewed. An example of an L_{day} difference grid is presented in Figure 1 below.

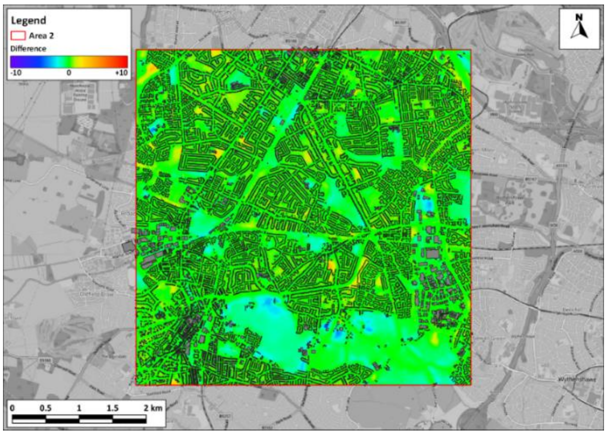

Figure 1: Example L_{day} Difference Grid – LCM 2019 vs OSMM Topo (Area 2)

Table 4 shows that the CLC 2018 models completed calculations more quickly than the LCM 2019 model for both Area 1 and Area 2, however the LCM 2019 model still show a significant improvement in terms of reducing calculation times, (49% of the OSMM Topo benchmark model for Area 1 and 38% of the OSMM Topo benchmark model for Area 2).

Table 4 also shows that the results from all test models could achieve an uncertainty criterion of ± 2 dB(A) for Area 1 and Area 2 across all statistical parameters, with the exception of the range. The differences illustrated by the range compared to the 95% C.I. highlight that there may be a small number of outlier results for certain propagation scenarios which are highly sensitive to ground cover dataset selection.

The difference grids across Area 2 suggested that both datasets would perform similarly in terms of the extent of the uncertainty introduced into the results, when compared against the OSMM Topo benchmark model across urban and suburban locations. Across Area 1, the CLC 2018 vs OSMM Topo difference grids indicated large areas where the model had calculated higher levels in comparison to the OSMM Topo benchmark model, as a result of the low spatial resolution of the CLC 2018 data. The same issue had not presented itself in the results of the LCM 2019 model, which has performed better overall in terms of consistency than the CLC 2018 model, when compared to the OSMM Topo benchmark model.

5. CONCLUSIONS

5.1 Addressing the Discontinuity Resulting from G = 0

The RIVM Letter report 2019-0023 identified an issue where there would be a discontinuity in results for instances in which all ground along the source to receiver path has G = 0. To avoid this discontinuity, it is recommended that where G = 0 it should be redefined as G = 0.0001.

5.2 Recommended Ground Absorption Factors

It is understood there is a legal requirement to consider the values of G presented in Table 2.5.a of Directive 2015/996. The descriptions in Table 2.5.a of Directive 2015/996 are broad enough to enable the assignment of ground factor coefficient G values to all the land cover descriptions described within the three tested ground cover datasets, however it is recommended to expand upon these values based upon the findings of the research (as presented in Table *1*).

5.3 Consideration of Road Surface, Slab Track and Rail

It is understood that it is necessary to ensure that areas of road surface, slab track and ballasted track are specifically present in the ground cover dataset so that they can be assigned the relevant ground absorption values as stated within Directive 2015/996.

5.4 Selection of a Ground Cover Dataset for Modelling using the CNOSSOS-EU method

The range of calculated levels presented in Table *4* shows that there are propagation conditions in which there were significant changes in calculated levels. This may suggest that the most detailed dataset (in both its geometric representation and attribution) should be selected when modelling using the CNOSSOS-EU method. However, when undertaking national coverage noise modelling, it is necessary to strike a balance between the complexity and availability of the dataset, the impact on calculation times, and the uncertainty in calculated results.

Basing ground cover upon OSMM Topo data was expected to provide the highest quality model dataset available due to the resolution of the geometry data, and the extensive range of more than 200 unique ground cover description classes. However, a comparison of model calculation times indicated that a model using OSMM Topo-based ground cover can take more than double the time to complete than a model using more generalised datasets such as the CLC 2018 or LCM 2019.

Comparison between the CLC 2018 and LCM 2019 datasets indicated that a ground cover theme based on processed LCM 2019 offered a better compromise, introducing a low level of uncertainty in the calculated noise levels and a large reduction in calculation time.

For national coverage noise mapping, it was recommended that the benefit of the time saved in calculation outweighs the uncertainty in the results introduced by using ground cover data based on processed LCM 2019, rather than OSMM Topo data.

Whilst a ground cover object based upon OSMM Topo data results in longer model calculation times, this is likely to be less of an issue for localised noise assessments, which are more likely to occur over much smaller areas than at a national level, therefore the additional calculation time associated with using this dataset is a less important consideration, thus the increased resolution of OSMM Topo may be seen as a preferable dataset in such scenarios.

6. ACKNOWLEDGEMENTS

We would like to thank Defra for commissioning the study.

7. REFERENCES

1. Department of Transport, Welsh Office. Calculation of Road Traffic Noise (CRTN). London, Her Majesty’s Stationery Office (1988)
2. Department of Transport, Calculation of Railway Noise (CRN). London, Her Majesty’s Stationary Office (1995)
3. CORINE Land Cover. [Online]. Available: https://land.copernicus.eu/pan-european/corine-land-cover
4. DG Joint Research Center, Common Noise Assessment Methods in Europe (CNOSSOS-EU), Luxembourg, Publications Office of the European Union (2012)
5. Land Cover Map. [Online]. Available: https://www.ceh.ac.uk/ukceh-land-cover-maps
6. OS Mastermap Topography Layer. [Online]. Available: https://www.ordnancesurvey.co.uk/business-government/products/mastermap-topography
7. Sétra. Road noise prediction - Noise propagation computation method including meteorological effects (NMPB 2008). Bagneux, June 2009
8. European Civil Aviation Conference. ECAC Doc29 4th Edition Report on Standard Method of Computing Noise Contours around Civil Airports. Neuilly-sur-Seine, December 2016
9. Official Journal of the European Union. Commission Directive (EU) 2015/996. The European Commission, May 2015
10. Official Journal of the European Union. Commission Directive (EU) 2021/1226. The European Commission, July 2021
11. Kok, A., and van Beek, A. Amendments for CNOSSOS-EU, Description of issues and proposed solutions, RIVM Letter report 2019-0023. National Institute for Public Health and the Environment (RIVM) (2019)
12. Improved Methods for the Assessment of the Generic Impact of Noise in the Environment WP1 Final Report. Guidelines and good practice on strategic noise mapping, ARPAT, February 2007
13. Liikenneviraston, 2017. CNOSSOS-EU-laskentamalli - Laskenta-asetukset ja mallinnusperiaatteet. Helsinki: Liikenneviraston
14. European Commission Working Group Assessment of Exposure to Noise (WG-AEN), Position Paper, Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure, Version 2, August 2007