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DEFRA'S NOISE MODELLING SYSTEM: A NEW APPROACH TO NATIONWIDE MODELLING IN SUPPORT OF RESEARCH AND EVIDENCE

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ABSTRACT

The United Kingdom Department for Environment, Food and Rural Affairs (Defra) commissioned the design and build of an environmental noise modelling system (NMS). The NMS has been developed to support Defra in preparing its environmental noise evidence base by preparing national road and railway noise models. Since its development in 2022, the NMS has successfully delivered national coverage noise models, noise maps and population exposure statistics for all public road and railways sources in England, Wales and Scotland. This paper provides an overview of the design of the NMS, the specific design choices made in its development, and how these design choices feature in models and noise exposure data can be used to support the development of re-search and evidence.

Keywords: *noise mapping, research, Defra noise modelling system (NMS)*

1. BACKGROUND

The UK Department for Environment, Food and Rural Affairs (Defra) commissioned the design and build of an environmental noise modelling system (NMS) in 2021. From inception, Defra has overseen the development of its NMS to ensure that it is capable of transforming the way in which Government can both understand the scale of impact of noise from road and railway sources across England, but also work with stakeholders to integrate their own data sources, provide access to the underlying noise model and results, and ingest and integrate other data sources to support research and develop evidence.

This paper focusses on how design choices in the NMS's development can be used to support the development of research and evidence.

2. NMS DESIGN OBJECTIVES AND REQUIREMENTS

The core functional requirement of the NMS is to deliver Defra's regulatory requirements by producing strategic noise models, maps and exposure datasets for relevant road and railway sources in England, along with preparing analysis to fulfil the requirements of the Environmental Noise (England) Regulations 2006 (as amended) [1], the Defra 25-year Environment Plan [2], and the Public Health Outcomes Framework [3].

These requirements set a design requirement for the NMS to deliver a national noise model and associated noise exposure dataset for England with all public roads and railway including in the noise model. An example noise model within England using the NMS is presented in Figure 1.

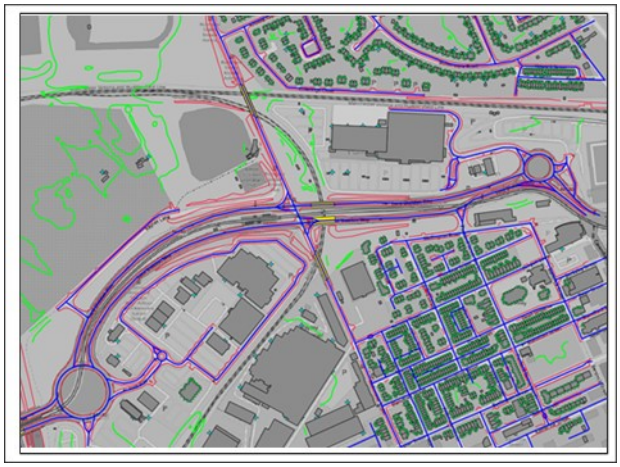

Figure 1. Noise model example highlighting road and railway sources, propagation model and façade receivers

The noise models delivered within the NMS are produced in line with the requirements of the adapted assessment methods based on the Calculation of Road Traffic Noise (CRTN), Calculation of Railway Noise (CRN), and CNOSSOS-EU. A design objective for the NMS is to deliver these requirements through automated processes wherever possible.

The wider design requirement for the NMS is to allow future users across the public sector to access the noise model through the NMS using open data standards.

For Defra, a key requirement of the NMS is to utilise and integrate noise exposure datasets produced from its model to support research and evidence building. It is this requirement which has driven design choices in how data is stored, processed and managed within the NMS, along with how national calculations and the NMS's noise calculation engine have been designed and configured.

3. CONCEPTUAL DESIGN

The NMS is designed as a web accessible cloud computing service hosted in Microsoft Azure. It has been designed to connect a series of components secured behind a web application firewall. The design of the NMS has taken a 'decoupled' approach which utilizes existing commercial products with 'ground up' development in areas such as its database design and Extract Transform Load (ETL) tools.

At the heart of the NMS is a Postgres geospatial database served on Azure CosmosDB. The database has been designed to store noise models and noise exposure datasets alongside each other. In support of Defra's requirements, the NMS has been designed to deliver automated processes whereby selected input datasets are transformed into noise model datasets using Feature Manipulation Engine (FME) software running bespoke ETL tools.

The models are stored in a manner which conforms to its system's open data standards which have been developed in parallel with the NMS. The parallel development of the database alongside the open data standards has highlighted where and how relationships between the datasets held within the NMS can be established and where these relationships can be extended to external data sources.

A core principle in the conceptual design has been to retain internal and external relationships in the noise source, propagation, receiver and noise exposure results datasets. To achieve this the design concept has relied on retaining identifiers through the calculation process which has required developments to the NMS's calculation engine, which utilises LimA calculation cores.

The high-level design of the NMS and its components is presented in Figure 2.

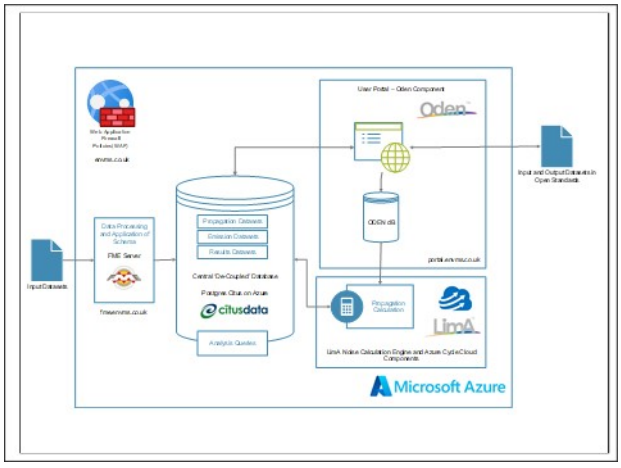

Figure 2. High Level Design of the NMS, its associated components and indicative data flows

4. DESIGN CHOICES AND FEATURES

In developing the NMS, specific design choices were made as part of the data and database architecture to support and facilitate the use of Defra's noise model and exposure

datasets to support research and evidence building. Three key design choices with this end use in mind are discussed.

4.1 Statistical Relational Modelling

A key design choice has been to develop a relational dataset which allows receptor datasets (buildings and noise calculation points) to be joined directly to results datasets stored in the NMS with wider external relational information to facilitate integration with wider Government statistics and data.

Each receptor at a building is provided with its own ID which is linked to each building. Each residential dwelling is pre-computed with population estimates. Each receptor is fed into the NMS's calculation engine with the results provided back to the database with reference to the receptor.

Each building is marked with relevant external identifiers that allows it to be assigned to various statistical geographies as defined by the UK Office for National Statistics. These geographies include Output Areas, Lower Super Output Areas, Ward Code, and Local Authority District Codes. Health Geographics are also assigned [4].

Using the CNOSSOS-EU 2a method for consistency, the database has been designed to allow noise exposure values for a range of metrics to be assigned to each building in 1 dB bands which are stored within the NMS as a dataset.
The retention of relational identifiers with Government statistical geometries within the NMS data model facilitates wider Government statistics to be joined to noise exposure datasets.

To support this, an end user tool referred as the 'Joint Statistics Tool' (JST) has been developed and is hosted within the NMS itself. This tool has been developed so that statistical data can be proportioned to a building level based on population estimates. This approach allows population noise exposure in 1 dB bands as held at building level to be considered based on the likelihood of that population falling into other statistical categories. An example is presented in Figure 3 which indicates how a general health statistic can be joined to noise exposure.

4.2 Source Apportionment

The NMS data model has been developed so that road and railway noise levels at each façade receptor and each grid calculation point can be revealed. This logic can be extended to incorporate noise exposure levels from industry and airport sources allowing the contributions from each noise source at location to be understood.

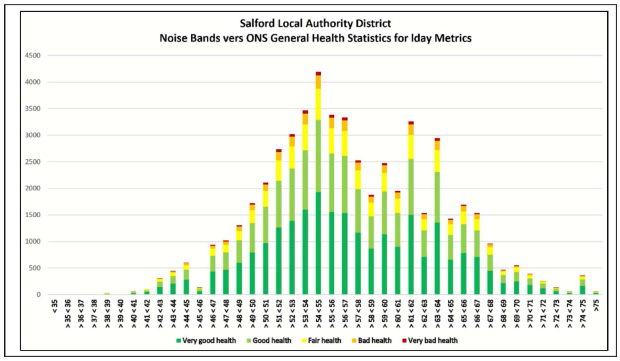

Figure 3. Example of an external statistic joined to noise exposure at building level

For road and railway sources, the concept of source apportionment has been further extended. Developments to the NMS's calculation core allows the contribution from individual road and railway sources to be understood with the contribution from each segment presented in order of its contribution to the overall noise exposure level by noise metric. This logic allows for noise emission parameters within the model to be presented alongside each contribution to provide an end user with an understanding of model inputs alongside their contribution to noise impacts. This is again achieved by retaining and reporting noise level contributions by source identifiers held in the model as stored in the central database by retaining these identifiers through the calculation process.

An example output from the NMS's source apportionment tool is presented in Figure 4.

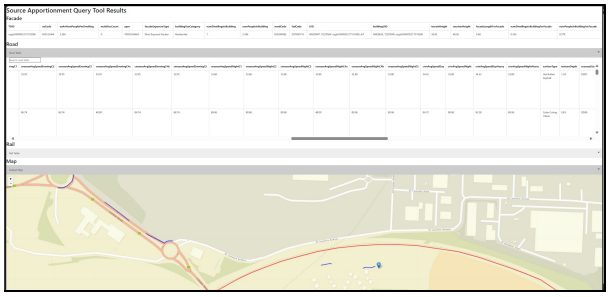

Figure 4. Example output from the NMS's source apportionment tool

4.3 Octave Bands

CNOSSOS-EU requires calculations to be carried out in octave bands. A key design choice has been to retain calculated octave band noise levels for each metric as part of the road and railway noise calculations. The NMS's database design and results tables allow octave band data to be stored for overall levels and as part of the source apportionment logic. Octave band results datasets are stored for façade receivers and noise grids.

Example road traffic noise maps calculated at the 1kHz and 250Hz octave band centre frequencies are presented in Figures 5 and 6 respectively.

Retention of octave band data allows the source and propagation characteristics to be captured over large areas and at discrete receptors opening up the potential to consider exposure relationships based on the character of the noise received.

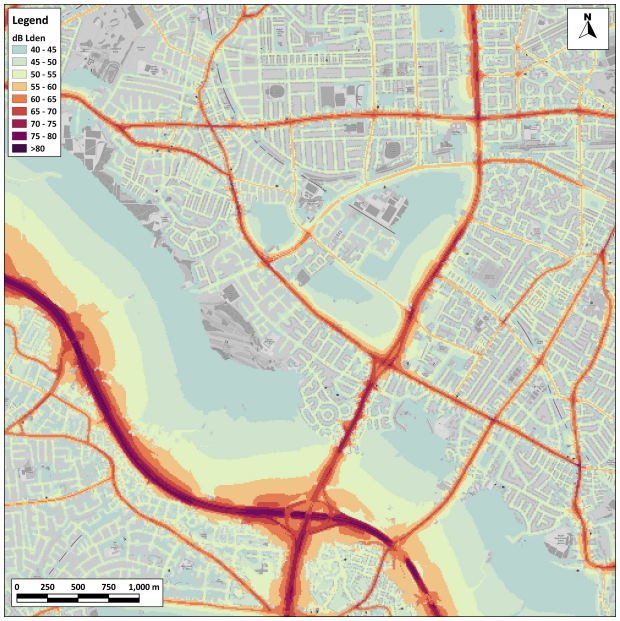

Figure 5. Road traffic noise maps (L_{den}) based on calculated levels at 1kHz

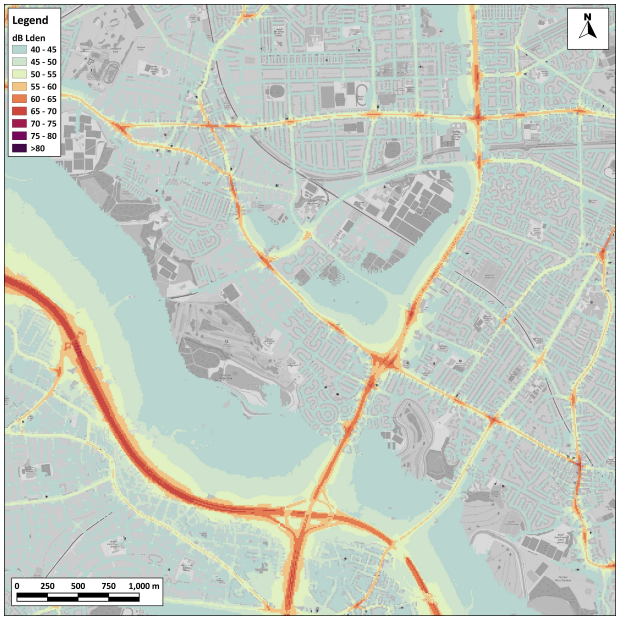

Figure 6. Road traffic noise maps (L_{den}) based on calculated levels at 250 Hz

5. OPPORTUNITIES FOR EVIDENCE AND RESEARCH

Section 4 of this paper highlights three key design choices within the NMS which provide opportunities for evidence building and research.

5.1 Inequalities in noise exposure

The NMS's Joint Statistics Tool provide opportunities for Defra to utilise its national noise exposure dataset to explore inequalities in noise exposure to individual transportation sources and/or combined transportation noise.

Using the JST, external datasets held by UK ONS as prepared using outputs from the 2021 Census [5], can be considered against exposure to environmental noise facilitating research and evidence generation exploring inequalities against a range of socio-economic and socio-demographic factors.

5.1.1 Socio-economic Factors

The National Statistics Socio-economic Classification (NS-SEC) is a standard classification which the UK ONS use to assign information such as occupations, employment status and history in statistical geographics across the UK [6]. ONS datasets also provide information that describe other

information such tenure of household and area-level income deprivation.

This data is held across a range of statistical geographies however through the JST this can be reconciled to building level allowing population and household noise exposure in 1 dB bands to be considered alongside statistical descriptions representing the likelihood that the population at each building falls into a particular socio-economic classification.

When considered and enumerated at regional and/or national level, the JST provides Defra with the opportunity to consider whether inequalities in noise exposure exist with respect to:

- Employment and Unemployment;
- Occupation;
- Household Income;
- Property Values;
- Household Tenure and Type;
- Income Deprivation; and
- Education.

5.1.2 Socio-demographic factors

The same techniques available in the JST provide opportunities to consider noise exposure against socio-demographic factors, namely ethnic group and household composition. The data model therefore provides Defra with the ability to consider whether there are systematic differences in exposure to environmental noise and different groups of people.

5.2 Mixed Source Environments

The NMS provides a national picture of exposure to transportation noise sources. In agglomerations, this is supplemented with exposure to industrial noise. This data is held in a standardised and consistent manner. The main evidence base for the effects of environmental noise still focuses on source-specific impacts and does not incorporate combined exposure to effects of multiple noise sources and/or other pollutants. The NMS and its data model provides opportunities to consider the effects of noise in mixed source environments. The national coverage of the exposure datasets provides further consideration to be given to the combined effects of other pollutants.

Defra carry out regular nationally representative social surveys on attitudes to different aspects of the environment and the work that Defra is responsible for [7]. These surveys include questions on people's response to different noise sources experienced whilst at home. Combining these results with outputs from the NMS provides the opportunity to look at exposure-response relationships at a national level.

5.3 Outcome Mapping

With noise exposure metrics stored alongside population at building level, the data model developed for the NMS provide opportunities to explore how harmful effects due to exposure to environmental noise can be mapped by calculating the number of people highly annoyed, highly sleep disturbed and/or at risk of health outcomes using odds ratios (OR) at building level and enumerating this information into zones, clusters, or within statistical and/or health reporting geographies to geographically map and identify burden through metrics such as Disability Adjusted Life Years (DALY).

The ability to store temporal data allows trends to be tracked over time.

5.4 Impacts on Biodiversity

Ecological research now deals increasingly with the effect of noise pollution on biodiversity [8]. Although habitats are not specific receptors in Defra's model, the national coverage of its noise exposure maps and grids cover biodiversity sites such as:

- Ramsar;
- Special Protection Areas (SPA);
- Sites of Specific Scientific Interest (SSSI); and
- Special Areas of Conservation.

These sites are designated in England as important for wildlife and other factors such as geology. Defra's datasets allow noise exposure to be considered across these areas, with octave band exposure datasets providing the ability for road and railway noise exposure to be considered using different frequency weightings and/or at specific frequencies which may best reflect the hearing characteristics of different species.

5.5 Tranquility Mapping

Outputs from the NMS have already been used by Welsh Government and Natural Resources Wales as part of the development of national tranquility maps [9]. National road and railway noise maps have been combined with other

datasets and rulesets to calculate tranquility indices as presented in Figure 7.

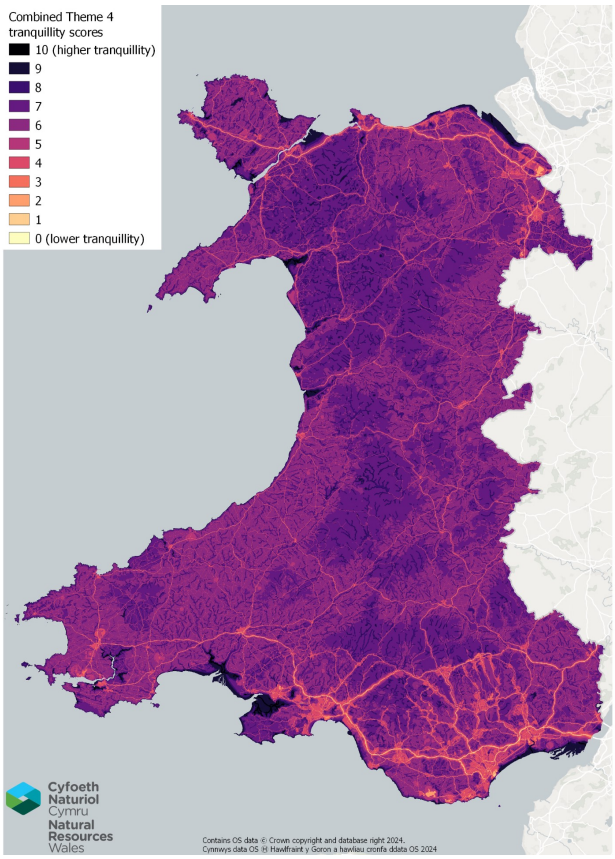

Figure 7. Tranquility map in Wales developed in part using NMS road and railway noise level grid outputs.

6. CONCLUSION

The development of the NMS has met the aims and objectives set out by Defra at the start of the project and even exceeded the expectations of many in the industry, It is the recipient of a number of awards for innovation from professional, government and non-governmental organisations. The NMS provides a solid foundation for building an evidence base over many years, with the flexibility to incorporate future datasets, not only related to noise modelling, but also wider environmental impacts or those associated with the broader built environment.

The above examples all show how the model and its outputs can be used to better understand the impact of environmental noise on the population. The data has also been used to enhance other indicators used widely in UK policy-making. The English Indices of Deprivation measure relative levels of deprivation in neighbourhoods in England [10]. In the next release, for the first time ever, environmental noise exposure to transportation sources will be one of the indices included in this composite measure. This would not have been possible had the NMS not covered all public roads and railway and the whole population of England.

7. ACKNOWLEDGMENTS

The development of the NMS has been a team effort. Defra would like to acknowledge the contributions from Noise Consultants Ltd, Acustica Ltd, Mott MacDonalds, NGIS, Stapelfeldt, M+P and ISVR

8. REFERENCES

[1] HM Government, *The Environmental Noise (England) (Amendment) Regulations 2018* (2018).

[2] HM Government, *A Green Future: Our 25 Year Plan to Improve the Environment* (2018).

[3] https://www.gov.uk/government/collections/public-health-outcomes-framework (accessed 28 March 2025)

[4] https://www.ons.gov.uk/methodology/geography/ukgeographies (accessed 4 April 2025)

[5] https://www.ons.gov.uk/census (accessed 4 April 2025)

[6] https://www.ons.gov.uk/methodology/classificationsandstandards/otherclassifications/thenationalstatisticssocioeconomicclassificationnssecrebasedonsoc2010 (accessed 4 April 2025)

[7] HM Government, Survey on Attitudes to the Environment (2021), https://randd.defra.gov.uk/ProjectDetails?ProjectId=20907 (Accessed 4 April 2025).

[8] R. Sordello, O. Ratel, F. Flamerie De Lachapelle, C. Leger, A. Dambry and S. Vanpeene: "Evidence of the impact of noise pollution on biodiversity: a systematic map," *Environmental Evidence*, 9, Article Number 20, 2020.

[9] https://storymaps.arcgis.com/stories/865c1876d9f64280a3dfc6e2769a46a5 (Accessed 4 April 2025)

[10] https://www.gov.uk/government/collections/english
-indices-of-deprivation (Accessed 4 April 2025)