Automation of a National Noise Model

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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. This paper discusses the automation aspects of the NMS with respect to the various elements required for a noise model. This includes the development of sophisticated data processing engines and the techniques utilised to automate the delivery of a 3-dimensional noise propagation environment, and road and railway noise emissions. It highlights several innovative methods which are now possible due to the data landscape in England and how through open data standards the NMS has the potential to improve the fidelity of national noise models.

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1. INTRODUCTION

The UK Department for Environment, Food and Rural Affairs (Defra) commissioned the design and build of an environmental noise modelling system (NMS). A functional requirement for the NMS is to support Defra in meeting its regulatory requirements to produce strategic noise models and maps 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) (the 'Regulations') [1], the Defra 25-year Environment Plan [2], and the Public Health Outcomes Framework [3]. These requirements are being delivered by producing a national noise model of with associated coverage, beyond the extents required by the Regulations. The noise models are being delivered in line with the requirements of the adapted assessment methods based on the Calculation of Road Traffic Noise (CRTN) [4] and Calculation of Railway Noise (CRN) [5], and CNOSSOS-EU [6].

A design objective for the NMS is to deliver these requirements through automated processes wherever possible. The wider design philosophy is to allow future users across the public sector in the UK to access the database through open standards for populating the noise calculation tools of their choice with Defra's noise model.

2. SYSTEM ARCHITECTURE

The NMS is designed as a web accessible cloud computing service hosted in Microsoft Azure. The NMS 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. At the heart of the NMS is a Postgre Citus geospatial database. The database has been designed to store noise models and noise exposure data. In support of Defra's requirements, the NMS has been designed to deliver a process whereby selected input datasets are transformed into noise model datasets using a Feature Manipulation Engine (FME). The noise model datasets can then be extracted from the Citus database and computed using the LimA noise calculation engine. The results from the calculations are then deposited back into the database. The models and results are accessible through a user portal which is based on the Oden software system.

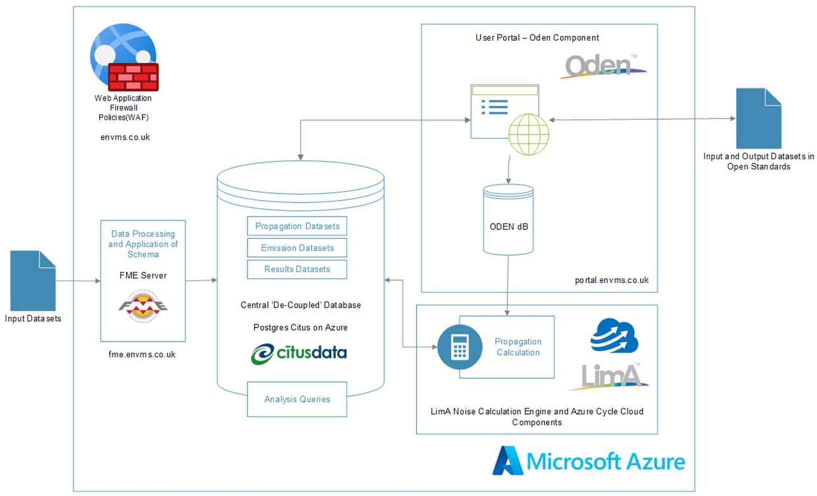

Figure 1: High Level Component Design of the NMS

3. DATA LANDSCAPING AND STRATEGIES

Noise modelling is underpinned by both spatial and non-spatial data. The data which is selected forms the basis of how the modelling is undertaken and how environmental noise is reported due to the transformations, processes and if applicable, assumptions which are to be implemented.

As part of the design and development of the NMS a comprehensive review of England's data ecosystem was undertaken against the input data requirements of the CRTN, CRN and CNOSSOS-EU methods to ensure the most optimal source datasets were used. The strategy was to treat data as a key asset from the start to understand its quality and ensure value adding opportunities to improve on the quality, and to maximise on innovative data automations to optimise time and cost-effective outcomes. This focused on using open data as much as possible as available through Open Government License (OGL) or similar licensing models, as well as data available to government organisations through the Public Sector Geospatial Agreement (PSGA). Commercially available data was considered where necessary.

The broad approach for the input data assessment was to consider its fitness for purpose, accuracy of the resulting noise model and costs associated with any data licensing. A systematic data quality review process was implemented to first screen available datasets against six dimensions of data quality (**Figure 2**). Any dataset which passed initial screening was then subject to a detailed assessment against extended criteria. Any data gaps were identified early in order to establish appropriate data gap filling strategies and understand the influence on the overall noise modelling accuracy. The benefits of this source data strategy included a common framework to review any future available datasets on accessibility, accuracy, completeness, consistency, timelines, and authoritativeness as well as interoperability and integration qualities. This ensured the best use of available data and data relationships to support an effective and sustainable noise modelling system for Defra's purposes that can ingest data from trusted and verified sources.

Figure 2: Six data assessment criteria for data fitness for purpose in noise modelling

Over 50 available datasets covering the propagation, sound source and analytical data themes were identified and screened against the data quality framework to recommend over 30 datasets that met the requirements of the NMS and were the best fit for purpose. These included, but were not limited to, data from Ordnance Survey Mastermap Topography Layer, Environmental Agency LiDAR Composite DTM and Department for Transport Road Traffic Statistics data. National Highways webTRIS road traffic data was also used for the first time in England's noise modelling, with detailed rail movement and rail fleet datasets used to allow line level modelling of rail emissions for the first time. The applicability of the data for use in other UK Devolved Administrations was also identified should the NMS be extended into other areas.

Stakeholder engagement was also part of the data landscape review to ensure available data publishers had been identified, their data assets assessed for use in noise modelling, and workshops held to keep key contributors involved.

As part of England's data landscape review for noise modelling application, opportunities were identified to improve the national data ecosystem including: the development of a three-dimensional (3D) national topographic mapping data; three-dimensional road and rail centerlines; three-dimensional bridge datasets; and national road and railway flow models.

3.1 Automated data-driven modelling of 3D noise environment and noise sources

Noise calculations require propagation and road and rail noise sources data to be analysis ready. This means the data is prepared for noise analysis without having to pre-process source data that comes from multiple disparate sources, in various standards, structures and formats. To date, data-driven approaches for noise modelling in England have been based on semi-automated data pre-processing to propagation and sound source models which can require extensive manual effort. This is, amongst other aspects, due to the lack of fit for purpose 3D data at national scale. Therefore, it was necessary to develop a consistent 3D model in which noise propagates to model complex road and rail junctions in 3D.

One of the key criteria was to ensure the flow of data through the NMS is automated as far as possible in a cost-effective manner. The NMS has systemised and automated most of the data pre-processing, for both propagation and sound source models, through development of innovative digital solutions based on sophisticated data processing engines. This has utilized spatial Extract, Load and Transform (ETL) in FME and developed analytics to automatically transform and integrate multiple input datasets from their source data schemas to the NMS central database schema developed in line with Open Data Standards which were developed for the NMS. This solution transforms multiple source data at national scale to integrated propagation and sound source data models, ready to ingest to the main database, a digital heart of the system and potential single source of truth, for use in noise analysis. This involved developing and documenting 'business rules' to govern the data-driven and rule based automated processing, as well as extensive testing and validation of the results to ensure the required quality and accuracy. Where possible, application programming interfaces (APIs) were used to read data with data science approaches adopted to fill data gaps, particularly for the preparation of road sound source traffic flow. **Figure 3** shows the example results from the automated processing of the road sound source data to obtain distance to junction information needed for noise modelling junctions and roundabout corrections in CNOSSOS-EU.

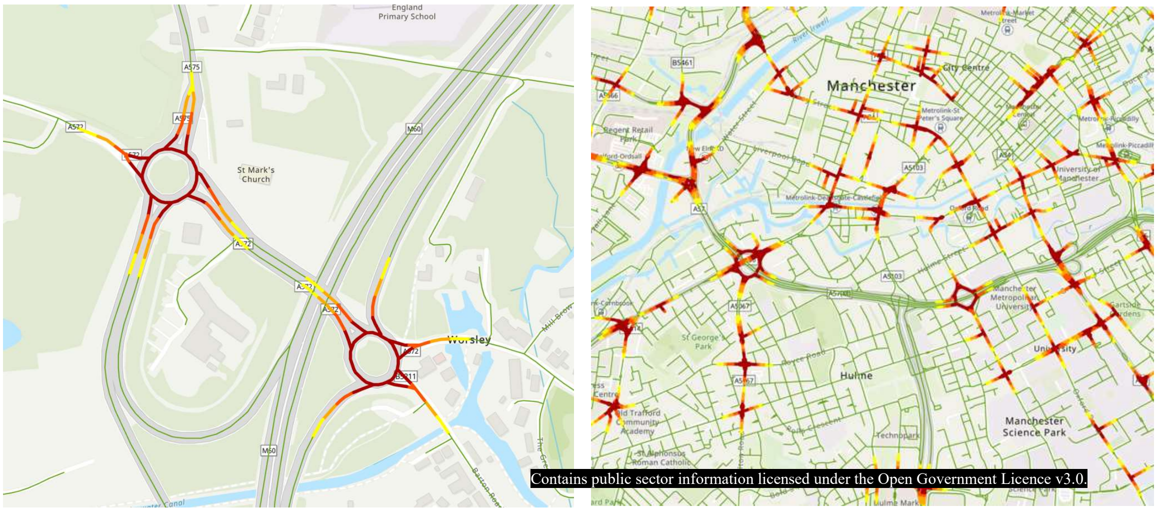

Figure 3: Road sound source centreline coloured by distance to junctions – example of automated processing results

Over 24 tools have been developed as part of the NMS data engine so to automate the processing of propagation and road sound source model generation as well as the majority of rail sound source processing. The solution achieved new levels of efficiency in national noise model creation, and greatly facilitated consistency, auditability, and repeatability of the end-to-end digital and automated noise modelling allowing the process to be reproduced.

3.2 Data management and Open Data Standards

The management of spatial and non-spatial data has been an important aspect of the overall system design. To help manage the effective flow of data through the NMS, data management design principles based on a seven-layer data architecture were adopted (**Figure 4**): 1-Source, 2-Adapt In, 3-Transform In, 4-Canonical, 5-Transform Out, 6-Adapt Out and 7-Target. Metadata has also been incorporated to provide information on data, origin, lineage, quality and other information.

The Source layer represents a wide range of input datasets in their native data standard which are validated at the Adopt In stage, where no content is modified. The data is then transformed in the key value adding process where data is pre-processed to create analysis ready data, such as 3D propagation model and sound source model datasets, conforming to open data standard and formats for homogeneity and conformity. This data is then loaded to the database, representing the Canonical stage.

The canonical layer at the centre of the process represents the Citus database and holds the NMS data in a relational database structure which aims to present data entities and relationships in a simple form. The database holds all the data layers for the source emission models, propagation model, calculated receiver results, analysed statistical results, and graphical noise maps.

This enables the Transform Out stage where data is represented to match the target data structure. The Adapt Out stage applies data schema to prepare data to load into target data tables and finally Target stage, which is the destination of the data, ready for use in noise modelling applications.

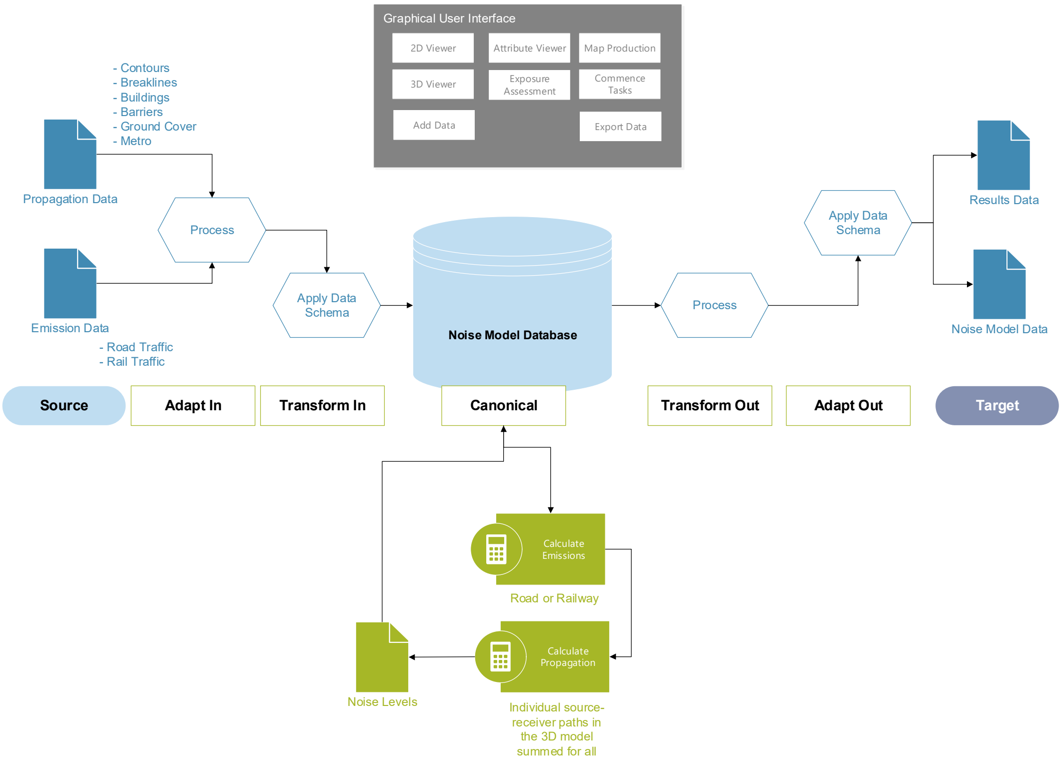

Figure 4: Seven-layer data architecture for data management

Open data standards were developed to ensure data is processed to open formats, for example, GML, and to open the system to wider stakeholders. This approach allows the system to ingest data directly and promote the use beyond Defra's requirement and potentially beyond the domain of noise modelling. Through open data standards, users and organisations can publish, access, share and reuse quality data from the NMS.

Open data standards provide consistency in the definition, meaning and use of data through the NMS by providing standard definitions to those who commission, build, populate and analyse the NMS data. The development of standards facilitates data interoperability within the NMS and across other software and systems consistently with a common data model. The adoption of such standards also enables version control and future updates and improves fidelity of national noise models through a defined and transparent model of data components.

2.3 Data Innovations

Innovative approaches have been taken within the data engines so to advance the noise modelling from a semi-manual process to a data driven and rule-based automation. This was achieved by cross discipline collaboration of subject matter experts, connecting noise domain expertise with digital innovations in data and analytics. As highlighted in **Figure 5**, a key aspect of this has been to fully automate the propagation model in 3D with associated acoustic and analytical attribution so that noise calculation engines do not need to perform such transformations themselves. A further innovation has been the use of relational keys to allow both the noise model data layers and results to be queried within the Citus database.

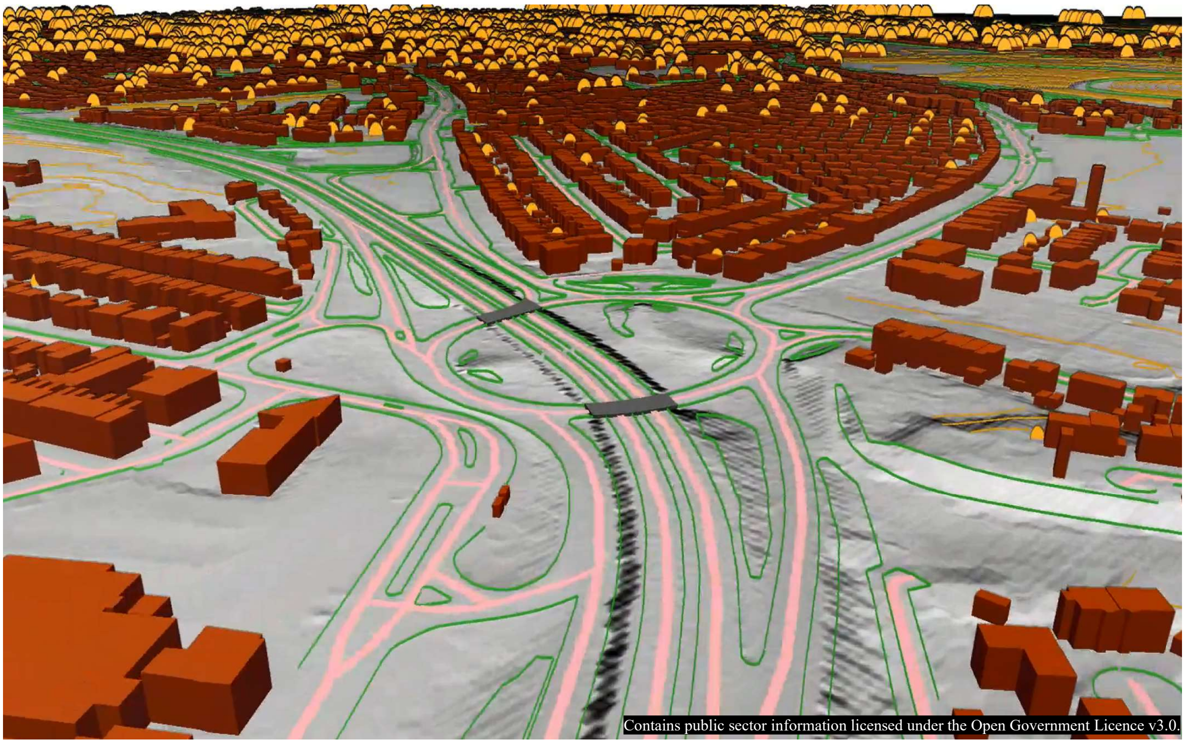

Figure 5: Three-dimensional noise propagation model

4. COMPUTATION AND ANALYSIS

The NMS uses LimA calculation cores to compute the noise models held in the NMS database. To achieve this, new and modified modelling objects were designed into LimA to reflect the open data standards, with extraction routines developed alongside a set of database views. These routines allow data to be extracted based on geospatial queries or by Ordnance Survey tile references. Key to this process is the retention of relational identifiers for all modelling objects as they pass through the LimA calculation core and into the results datasets generated. For example, façade receptor IDs held in the NMS are retained during calculation with calculated noise levels reported against these to allow the data to be joined back to objects held within the analytical layer of the NMS database. Source appointment has also been designed into the calculation process allowing the contribution of road and rail sources to be output alongside the ID of the emission objects themselves. This provides opportunities for end users to query noise emission data alongside noise exposure data in a manner which has not been possible at a national level to date.

Delivering calculations on a national scale requires significant calculation resource. The NMS has been designed to automate the delivery of the calculations by scaling up dedicated calculation resource using Azure CycleCloud. The design allows around 1000 CPUs to be deployed with CycleCloud detecting and scaling this resource across a number of virtual machines known as 'worker nodes'. Upon completion of the calculations, the worker nodes automatically upload calculated noise levels back to the Citus database where relational queries are then run. The process means that other than the calculation, the there is no reliance on the LimA component in either building the noise model or processing the results.

5. CONCLUSION

Defra's NMS has sought to automate the preparation and calculation of an English national noise model. To facilitate this a comprehensive review of the data landscape has been undertaken, along with stakeholder engagement activities. Automated generation of the noise model datasets have been delivered through ETL processes working to open data standards. This approach allows the noise models to be compatible with other software tools and systems. To achieve this, many of the processes which would normally be delivered within noise calculation software tools were made external in FME. The delivery of noise calculations at a national level requires significant calculation resource to be made available. This has been delivered in Microsoft Azure using CycleCloud and automatic model extraction routines. By maintaining object identifiers in its database and through the calculation process, queries can be delivered which connect emissions with exposure. This provides further opportunities to understand noise impacts at a national level.

6. ACKKNOWLEGEMENTS

We would like to thank Defra for allowing us to present our work on its NMS.

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