Strategic noise mapping in France to 2023: Coupling a national database with the open-source software NoiseModelling

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ABSTRACT

The Environmental Noise Directive (END) requires the realization of strategic noise maps, every 5 years, to asses the noise impact of roads, railways, airports and the main industries on the inhabitants. To achieve round 4 for major roads and major railways, the French government has decided to create a national database called PlaMADE, which gathers all the necessary input data (traffic, building, population, relief...) in a unique format, a french GeoStandard by COVADIS. On the basis of these data, and using the open-source noise propagation calculation tool NoiseModelling, all the indicators and maps have been produced for the first time in an automatic way at a national scale. This paper presents the technical and methodological details of the coupling between the PlaMADE database and the NoiseModelling tool.

1. INTRODUCTION

The European Directive 2002/49/EC requires, every five years, the characterisation of the noise exposure of major road, rail and air transport infrastructures impacting local residents [1]. The

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General Directorate for Risk Prevention (DGPR) of the french Ministry of Ecological Transition has entrusted the Cerema (Centre for Studies and Expertise on Risks, the Environment, Mobility and Planning) with the production of strategic noise maps on a national scale for all road and rail land transport infrastructures carrying, respectively, traffic in excess of 3 million vehicles per year (8,219 vehicles/day) or 30,000 trains per year (82 trains/day). To facilitate the creation of these maps, the COVADIS French GeoStandard "environmental noise" was published in 2019 [2]. It proposes to provide a common vocabulary and data structure to the actors involved in the creation of environmental noise prevention plans and strategic noise maps in order to harmonise the provision of input data to noise emission and propagation models.

In the context of 3rd round (2017) of the 2002/49/EC, Cerema had developed an extension to the QGIS GIS software, called Mizogeo[5], to facilitate the work of bringing the databases of each of the managers in line with the GeoStandard and to publish their maps. For the 4th round (2022), Cerema has set up the PlaMADE project (*Plateforme mutualisée d'aide au diagnostic environnemental*) by creating a database of the properties of major road and rail land transport infrastructures throughout the French network.

As pointed out by King and Rice [3], the philosophy of the European directive 2002/49/EC, and more generally the context of the European INSPIRE directive [4], should motivate the use of open-source geographic information system software (GIS), instead of black-box implementations of comparable commercial software. The open-source software NoiseModelling[6], jointly developed by the Gustave Eiffel University and the French National Centre for Scientific Research (CNRS), is in line with this approach. NoiseModelling was first published on the GitHub platform[7] in 2010. In the last years, this tool has had many contributions, in particular by integrating the CNOSSOS-EU method, allowing the calculation of noise emissions and propagation as required by Directive 2002/49/EC. All the elements were thus gathered for the production of noise maps on a national scale, by coupling the PlaMADE database with the NoiseModelling tool.

2. DATABASES

2.1. Geostandard "Environmental noise"

For the implementation of the noise mapping imposed by the European directive, there is a great multiplicity of competences and actors in France and therefore essential needs for the exchange of standardised data. The French GeoStandard "environmental noise" edited by COVADIS (*Commission de validation des données pour l'information spatialisée*, *Data Validation Commission for Spatialized Information*) therefore meets this need. The scope of the standardised information in Part 1 (entitled "Noise Mapping", version 1.1 of 8 June 2017) of the GeoStandard essentially concerns the modelling of environmental noise output data: this concerns, on the one hand, the high noise impact areas, noise black spots and perimeters of environmental noise prevention plans, and, on the other hand, isophones and noise areas of the acoustic indicators within the framework of the diagnosis of strategic noise maps. Part 2 (entitled "Input Data", version 1.1 of 12 march 2019) describes the environmental noise input data required for the calculation of the different noise indicators, including the geometry of noise sources: this concerns sections of land transport infrastructure and the location of noisy industrial activities. For consultation, the full GeoStandard is available on the French Ministry's website[8].

[5]https://www.cerema.fr/fr/actualites/mizogeo-outil-mise-au-geostandard-cartes-bruit-strategiques

[6]https://noise-planet.org/noisemodelling.html

[7]https://github.com/Ifsttar/NoiseModelling

[8]http://www.geoinformations.developpement-durable.gouv.fr/geostandard-bruit-dans-l-environnement-a3604.html

2.2. PlaMADE

The collection of input data is a particularly time-consuming and resource-intensive phase. The input data used come from multiple, sometimes very heterogeneous sources (traffic data in particular). They may be reproduced or even duplicated by the various competent authorities, notably due to the lack of a unified, structured and permanent technical organisation. They also require at least reformatting, but more generally in-depth re-use, and sometimes even approximations that require skills that go well beyond acoustics. Due to a lack of organisation, the intermediate validation of input data by external suppliers or of output data by future users can increase the time required to produce the maps.

Following the publication of the COVADIS "Environmental Noise" French GeoStandard, it was decided that all the data required to produce strategic noise maps of non-concession roads and railways would be centralised in a national database, called PlaMADE for *Plateforme Mutualisée d'Aide au Diagnostic Environnemental* (*Mutualized Platform for Environmental Diagnosis Assistance*). This database makes it possible to gather all the input data necessary for the production of maps of ground surfaces, topography, buildings, speeds, road surfaces used, noise protection and average daily traffic. It also enables the storage of acoustic modelling files produced from these input and output data (maps, object tables...), which are useful, in particular, for drawing up noise action plans.

3. NOISEMODELLING

3.1. History

NoiseModelling is mainly developed by members of the Lab-STICC laboratory (CNRS) and by the Environmental Acoustics Research Unit (UMRAE, joint research unit between the Gustave Eiffel University and the Cerema) [5, 6]. NoiseModelling is a free and open-source software whose initial objective was to produce a road traffic noise map at the scale of the Nantes agglomeration for the EVAL-PDU research project in 2010 [7]. Since the first developments, the code has largely evolved, thanks to numerous contributions, in the care of several research projects and in particular, in the context of the present PlaMADE project. As an illustration, Figure 1 shows the history of lines (called 'Commits' within the context of the GitHub project plateform) added to the NoiseModelling source code since the creation of the GitHub repository.

Figure 1: Timeline of the GitHub commits within the NoiseModelling software since its creation. In yellow, the period of the PlaMADE coupling project with NoiseModelling.

In the first versions of the NoiseModelling software [8], the building height was considered as "infinite" (*i.e.* a 2D model) and the implemented road noise emission and propagation model was based on the NMPB-08 French standard [9]. NoiseModelling was thought to be compatible with spatial data structures and was integrated into the cross-platform open-source geographic information system OrbisGIS [10]. In 2014, the model included the third dimension *via* a 2D1/2 propagation scheme. In 2015, the OrbisGIS data manipulation engine switched to the H2 database management

system (DBMS), and its spatial extension H2GIS, providing new perspectives for data processing [11]. In 2018, the developments were continued in the framework of the CENSE research project [12]. The road traffic noise emission and propagation model CNOSSOS-EU was integrated in 2019. The noise modeling was redesigned by integrating a web interface and becoming independent of the OrbisGIS software, and the emission, propagation, and propagation path finding modules were separated. These important changes enabled the release of NoiseModelling version 3.0 in late 2019. Since version 4.0 (2022), NoiseModelling integrates the railway noise emission and propagation model CNOSSOS-EU [13]. The first NoiseModelling user days were organized online in March 2020 and have been held annually since then. The software has been regularly used in research projects for multi-source mapping of noise environments, dynamic mapping or to perform sensitivity analysis [14–16].

3.2. Open-source software

NoiseModelling is distributed under the GPL v3 license[9]. The GNU General Public License is a free and copyleft license for software and other works. It is possible to copy, distribute and modify the software as long as the trace of changes/dates in the source files is kept. Any modification or software that includes GPL-licensed code must also be made available under the GPL with compilation and installation instructions.

In addition, all tools or software used to develop and distribute NoiseModelling are also free and open source:

- The 'GitHub'[10] platform is used to store, version and archive source code;
- GitHub actions are used for continuous integration and automatic validation of unit tests;
- The online documentation[11] is provided with 'Read the Docs'[12] platform;
- 'Geoserver'[13] and 'H2GIS'[14] are used to process geographic information.

3.3. Software validity

For the validation of the CNOSSOS-EU model, the reader can refer to the corresponding documentation [13] and some publications [17, 18]. For the validation of the implementation, the software is completed by numerous unit tests, and its comparison with the tests published in the ISO/TR 17534-4:2020 [19] standard is available within the software source code. A set of tests is also integrated within NoiseModelling to avoid any risk of regression by the last developments. For a contribution to the source code to be accepted, all unit tests, ISO-related and regression ones must return the expected results. Thanks to the 'GitHub Action' service, the execution of this process is automated and is part of the continuous integration of the software.

4. COUPLING METHODOLOGY

When NoiseModelling is started, an H2GIS database is created to store and manipulate all the imported data needed to produce strategic noise maps. The PlaMADE input data are present in a

[9] https://www.gnu.org/licenses/gpl-3.0.html

[10] https://github.com/Ifsttar/NoiseModelling/

[11] https://noisemodelling.readthedocs.io/en/latest/

[12] https://readthedocs.org/

[13] https://geoserver.org/

[14] https://h2gis.org/

remote PostGreSQL/PostGIS[15] database stored on an internal Cerema server. As the data are not directly present in the H2GIS database of NoiseModelling, they must be imported. The first step is therefore to download and format the data from the PlaMADE database into the NoiseModelling database. In detail, the actions carried out are the following:

4.1. Server side

1. Reprojection into french legal projection systems[16] and indexing of geometric tables needed for NoiseModelling,
2. Generation of tables specific to NoiseModelling and not considered by the COVADIS GeoStandard (*e.g* configurations tables, favorable wind conditions, ...),
3. Generation of control metrics on raw data, allowing to warn on suspicious values (e.g abnormally high road traffic).

4.2. Client side

1. For a given department code, downloading the data according to attribute and spatial constraints,
2. Formatting tables to feet with NoiseModelling input data schema,
3. Quality control of imported data.

Subsequently, the following steps are done using a set of dedicated scripts within the NoiseModelling software:

1. Generation of evaluation points in front of buildings for exposure indicators and regular receivers grid for isophones generation,
2. Conversion of road and rail traffic into equivalent noise emission levels,
3. Calculation of sound levels at assessment points,
4. Generation of isophones,
5. Calculation of exposure indicators (*e.g* number of affected schools, exposed areas, ...).

A final step is to transfer the calculated data both to the database and the file server.

During the early stages of development, noise maps (V1) were manually generated by the Cerema team on a set of personal computers, following the previous steps. The final version of the noise maps (V2) was then fully automated *via* an easy-to-use platform that uses the power of a high-performance network at the Strasbourg University Computing Centre (CCUS)[17].

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[15] https://postgis.net/

[16] The input data are stored into WGS84 (EPSG:4326) projection system. To facilitate the upcoming treatments, we have to reproject them into dedicated french systems depending on the the study area (*e.g* Lambert 93 (EPSG:2154) for the metropole, ...)

[17] https://hpc.pages.unistra.fr/

5. PROJECT AGENDA

The coupling of the PlaMADE database with the NoiseModelling software was started on 1st January 2021 (Figure 2). A first version of NoiseModelling compatible with the PlaMADE database format was released in April 2021. Even if the work on the PlaMADE database started before the beginning of this project (2018-2019), the first official first delivery of the database (V1.0) in the GeoStandard format was made during July 2021 . The first maps (V1) were therefore calculated during the following months, in August and September 2021, for delivery in October 2021.

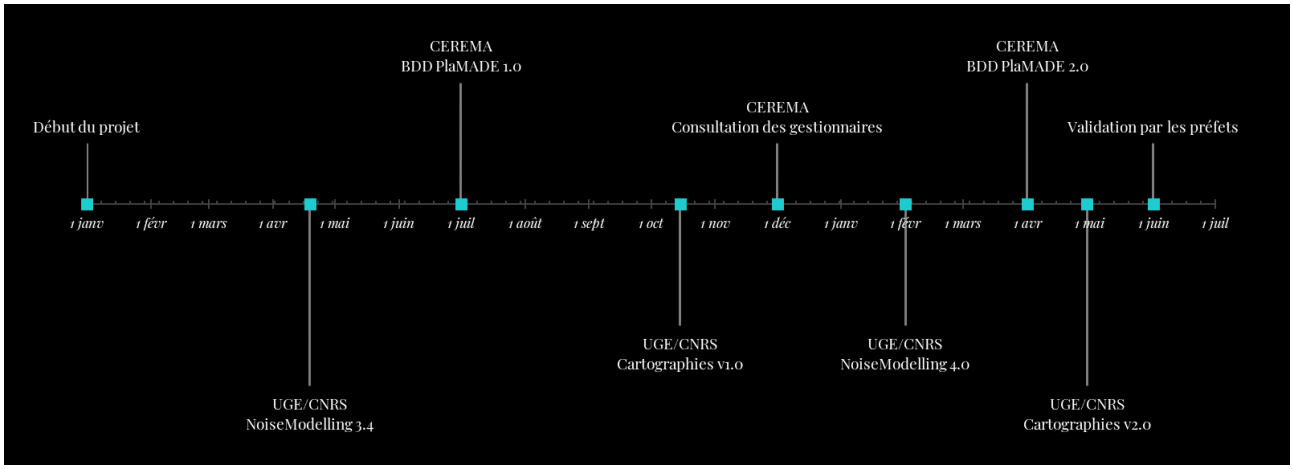

Figure 2: Timeline presenting the project agenda for the coupling between the PlaMADE database and the NoiseModelling software.

The maps were uploaded to an online consultation platform during the month of November 2021. The various road network managers were able to consult the maps and make modification requests in order to amend the database if necessary (omission of noise barriers, errors on traffic volumes...) from December 2021 to January 2022. In February 2022, version 4.0 of NoiseModelling was released, fully compatible with the GeoStandard, but also with the obligations of the European directive. February and March 2022 were dedicated to the reworking of the database for a new delivery at the end March 2022 (V2). The calculation of the V2 noise maps has been carried out until the end April 2022. This has made it possible to give about two months for the approval of the noise maps by the Prefects (official state representative in each French administrative region), with a June 30th deadline. Once approved, the maps will be uploaded to the European Commission's Reportnet 3.0 platform[18].

In the end, the automatic calculation of the noise maps was applied to the 73,000 km of the French national road network and the 6,000 km of the national rail network (figure 3). This represented the equivalent of 62.905 CPU hours during about 5 days of computation.

6. CONCLUSION

All the data necessary for the elaboration of strategic noise maps of non-concession roads and railways (traffic, building, population, relief...) have been centralized in a national database, called PlaMADE, under a unique format and respecting the French GeoStandard "Noise in the Environment" of COVADIS. This database has been coupled with the NoiseModelling software for the calculation of the noise emission and propagation, in order to produce the strategic noise maps.

[18]https://www.eionet.europa.eu/reportnet

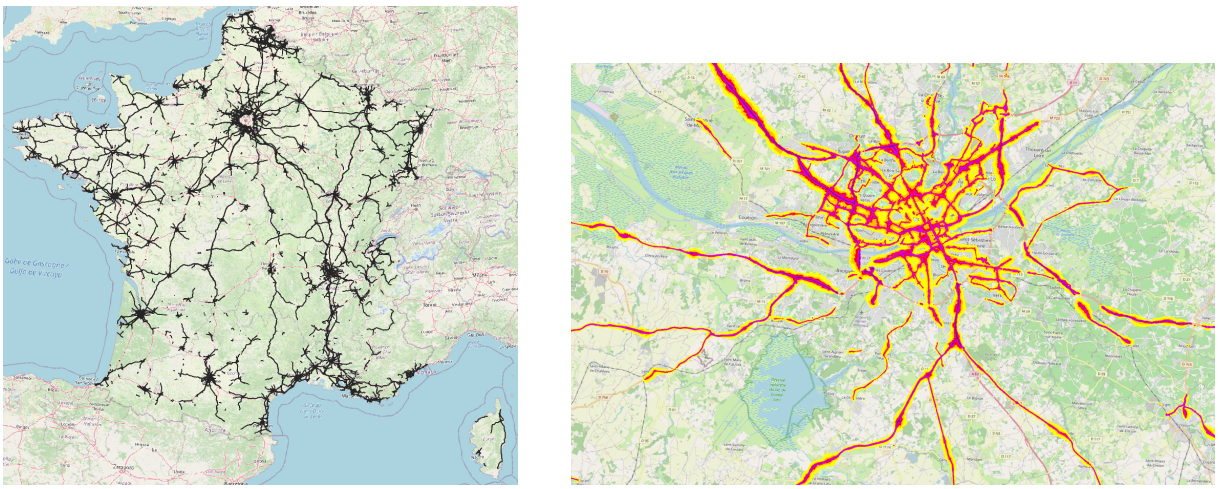

Figure 3: Left: Representation of the national road and rail network concerned by the elaboration of strategic noise maps. Right: Noise maps for the City of Nantes, France. Only a part of the road networks is considered for noise calculation.

Beyond the developments made to meet the 2022 deadline of the European directive, the interest of the application is that it can now be applied automatically as soon as a change is made on the PlaMADE database. The procedure is globally automated, and allows to realize all the noise maps of the non-concession road and rail networks in less than one week on a super computer. Without any major modification, this application can also be used to produce noise maps of urban areas, in France as well as in Europe.

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