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COMPARATIVE ANALYSIS OF STRATEGIC NOISE MAPS: USING HEAT MAPS TO FIND WHY TWO CNOSSOS-EU IMPLEMENTATIONS (INOISE AND CADNAA) DIFFER

Andrés L. Peña[1*]

[1] Calpe Institute of Technology, S.L., C/Severo Ochoa, 4, Málaga, Spain

ABSTRACT

Strategic noise maps are the tool to assess the population noise exposure, perform cost-benefit studies of the available measures to be adopted to abate that exposure as part of the noise action plans, and evaluate the effective improvement achieved after its implementation. CNOSSOS-EU is the homogenized calculation method for sound propagation outdoors in Europe, existing several applications implementing it. CNOSSOS-EU includes quality controls every application must fulfil, so no important deviations are expected in the results obtained when using different applications. However, such deviations exist and can be sensitive in some cases. The objective of this study is to present a method to detect where the disparities between both applications are more relevant: a heat map of the deviations obtained at the same grid point results, and an example of application in a real case scenario.

Two of these applications have been chosen, iNoise and CadnaA, to calculate the same strategic noise map of the population area of Santa Rosalía-Maqueda, Málaga. The different approaches in data processing and calculation method implementation of these applications are compared, the detected deviations in the outcomes obtained for both sound propagation and population noise exposure are analyzed, and the causes are inferred.

[*]***Corresponding author***: andres@caltech.es.

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1. INTRODUCTION

Noise mapping is the presentation of data on an existing or predicted noise situation in terms of a noise indicator, indicating breaches of any relevant limit value in force, the number of people affected in a certain area, or the number of dwellings exposed to certain values of a noise indicator in a certain area [1]. “Strategic” refers to maps designed for the global assessment of noise exposure in a given area due to different noise sources, or for overall predictions for such an area.

CNOSSOS-EU has become the homogenized calculation method for sound propagation outdoors in Europe, being the mandatory calculation method in most European states, starting from December 31, 2018 [2].

This method is paired with strict quality requirements and quality assurance methods defined in the ISO 17534 series, “to ensure, to indicate, and to verify the degree of conformity of a software program with a consistently implementable calculation method/procedure” [3]. Thus, given a certain dataset, any implementation of the CNOSSOS-EU should lead to the same results, this been checked by dozens of tests cases [4]. However, such deviations have been noted [5], and can be of statistical significance, even when assessing the sound power of sources [6].

Two different modelling software suites are compared in this study, DataKustik CadnaA® [7] and DGMR iNoise® [8], in the real case scenario of Santa Rosalía-Maqueda, a town area with a main through road and residential streets, being roads the only noise source considered. The comparison focuses on propagation differences detected. CadnaA was selected due to having access to a full working educational licence, and iNoise due to having access to a full commercial licence.

2. OBJECTIVES

The objectives are to compare the results obtained by both modelling implementations, minimizing the differences between the models loaded. To achieve this, minimal and unavoidable optimisations were applied to both models.
The author has no commercial or whatsoever interest in any of the two CNOSSOS-EU implementations used in this work, nor recommends the usage of one above the other.
Conclusions are applicable only to this case scenario, as no additional scenarios were checked for correlation.

3. METHODOLOGY

3.1 Data pre-processing

Data was gathered and pre-processed in QGis. Sources used were:

- Terrain digital model → MDT02 layer, 2nd coverage (2015 – up-to-date), with 2m grid spacing, Centro Nacional de Información Geográfica [10]
- Buildings → from Oficina Virtual del Catastro: layer CONSTRU for heights, and INSPIRE layer A.ES.SGDC.BU for layout, current use, construction date, number of dwellings (1 = single dwelling, 2 or more = multiple dwellings) and current status [11]
- Roads → OpenStreetMap project [12]
- Traffic flows and speeds → Plan for traffic flows from Junta de Andalucía, and WG-AEN [13] tool 2.5 where no data was available
- Population → DEGA (Datos Geoespaciales de Andalucía [14], evenly distributed between the buildings located in each data cell, but considering the volume of each building

The information was pre-processed and formatted for each software in QGis and then imported at CadnaA and iNoise.

3.2 Import process

Huge differences between CadnaA and iNoise data import interfaces were noted. While iNoise import/export process is clear, user-friendly and versatile, CadnaA has a completely different approach with a powerful but complex import interface but limiting the model data that can be exported.
As CadnaA allows a model to be calculated with several methods, item types have fields not used by CNOSSOS-EU (i.e., road width). As iNoise models are assigned to a calculation method at creation, the interface is adapted to it, and no unnecessary fields are shown.
Buildings and roads were directly imported and not simplified to minimise the differences between the models of each software. Height lines had to be minimally simplified, as CadnaA was unable to generate a 3D view if this step was avoided, and such a view is required to check for modelling errors. Terrain resolution has been proved to have minimal to no impact in the results [15].
CadnaA's tool to adapt the terrain digital model to avoid burial of roads in several points. While iNoise lacks such tool, these burials were avoided by rising all roads by 0,01m, which is trivial with its mass editing interface.
Road slopes were calculated at QGis, as CadnaA offers no direct option to export its calculated slopes and iNoise has no tool for calculating them.
Sound power levels of roads calculated by both applications were compared with almost no deviations between them, as Table 1 shows. Absence of integrity, duplicities and geometric errors were checked by iNoise for both items and terrain (CadnaA has no equivalent tool).

Table 1. Sound power estimation differences for roads by CadnaA and iNoise (dBA).

	$L_{w,d}$	$L_{w,e}$	$L_{w,n}$
Max, abs	0,450	0,450	0,660
Mean	0,026	0,005	0,101
Median	0,010	0,000	0,050

iNoise building item type has fields for designated use (i.e. residential, educational, industrial…) and dwelling type (no dwellings, single dwelling or multiple dwellings), while population data is managed with the address point item type. Address points are linked to residential buildings.
CadnaA building item type has a "residential" Boolean field and a population field, but there is no way to mark single or multiple dwellings.

3.3 Grid calculation

The calculation grid points were spaced by 2m in both dimensions, a high density, to better asses the differences in propagation obtained by both applications. Both models were not optimised for calculation but to minimise differences, so no conclusions can be made about performance nor efficiency of both applications, even when they both were run on the same server. Partial views of grid results are shown in Figure 1 (CadnaA) and Figure 2 (iNoise).

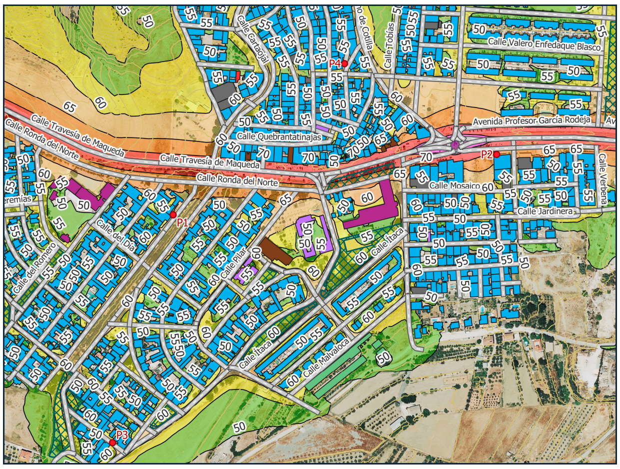

Figure 1. CadnaA grid results (L_{den})

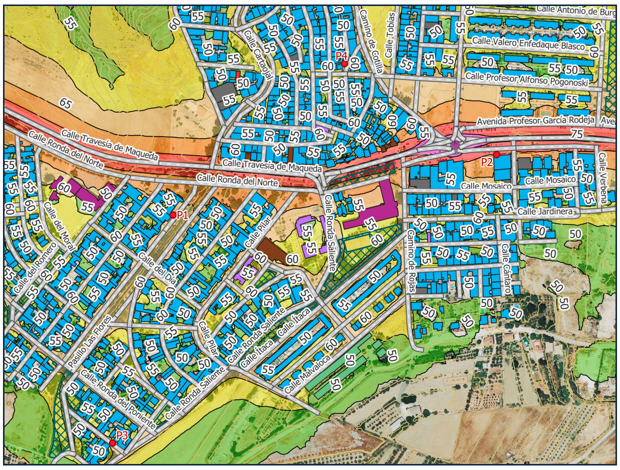

Figure 2. CadnaA grid results (L_{den})

3.4 Population exposure calculation

CNOSSOS-EU include methods 1 (most exposed), 2a (length) and 2b (median value) for population exposure calculation [16].

Unlike iNoise, CadnaA requires grid to be calculated prior to obtain population exposure, and by using the building evaluator item type. The façade exposure calculation method to be used can be chosen, but there is no option to use different methods for both single and multi-dwelling buildings.

iNoise has a tool to automatically mass add receivers at façades, which are calculated independently of the grid. These receivers are linked to the buildings, and the population exposure calculation may consider, if selected, different methods for façades of single and multi-dwelling residential buildings.

These radically different approaches to façade calculation might be behind the deviations detected in population exposure between both applications.

4. RESULTS

4.1 Grid results

As noted before, sound power of roads was estimated with minimal or no differences between both applications. However, sound propagated further according to iNoise compared to CadnaA. Grid point results were compared one by one, excluding those CadnaA and iNoise excluded (i.e., points located inside buildings). A statistical analysis (Table 2) of the deviations was carried out with the 72.388 grid points calculated by both applications. For each point, the iNoise result was subtracted from the CandaA result.

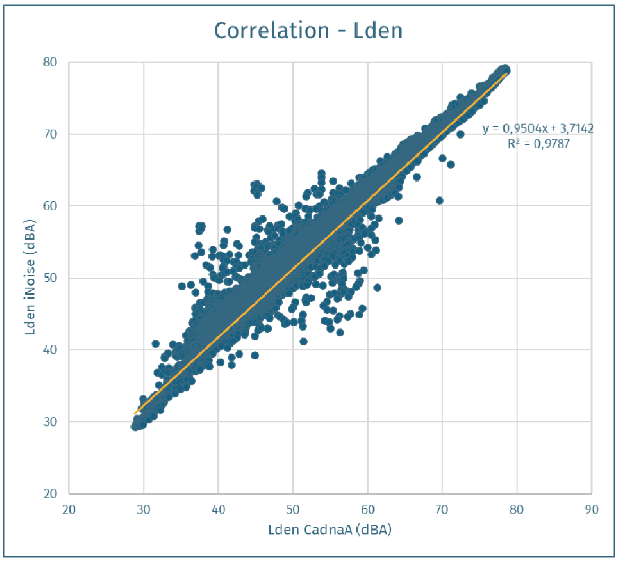

Figure 3. Linear correlation of grid points results

Considering L_{den}, CadnaA deviates >3dBA from iNoise in 105 points (0.15%), while the opposite happens in 3,769 points (5.21%). So, the difference at 68,514 points (94.65%) is in the (-3, 3) interval. A total of 43,530 points (60.13%) are in the (-1, 1) interval. Figure 3 shows linear correlation for L_{den} grid point results, with a Pearson r correlation coefficient higher than 0.97. A histogram for the same data is presented at Figure 4.

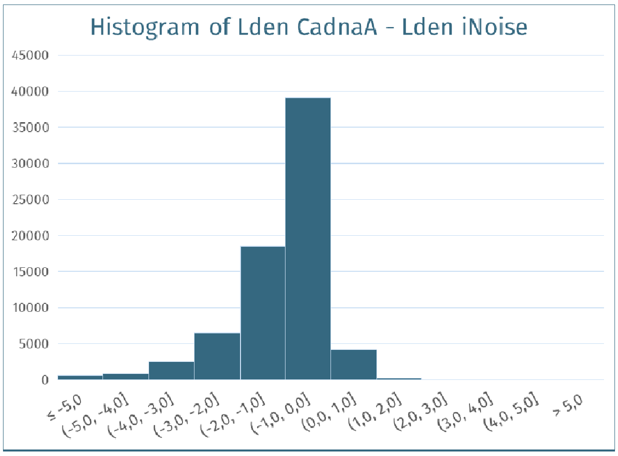

Figure 4. Histogram of L_{den} CadnaA - iNoise

To visualise the areas where the differences were located, the calculated differences were represented as a GIS layer, represented as a heat map as seen in Figure 5. Cold dots mean a higher value was calculated by CadnaA, and the warm areas are those where iNoise is the one estimating a higher result. This map allows examining not only the differences between the results, but how they are located, and may be the reason behind it.

Parameter	L_d	L_e	L_n	L_{den}
Max diff	14.03	14.16	14.04	13.97
Min diff	-19.29	-19.66	-20.08	-19.84
Mean	-0.95	-1.03	-1.04	-1.02
Median	-0.73	-0.78	-0.77	-0.76
Typ.Dev.	1.15	1.13	1.14	1.14
Variance	1.32	1.27	1.31	1.29

Table 2. Statistical analysis (CadnaA - iNoise)

The highest deviations are located 1) close to buildings, and 2) in complex terrain areas. Thus, obstacles as buildings or changes in terrain seem to have a lesser impact in iNoise than in CadnaA, as levels behind or next to obstacles tend to be higher in iNoise. Flat, open areas have almost equivalent results in both applications.

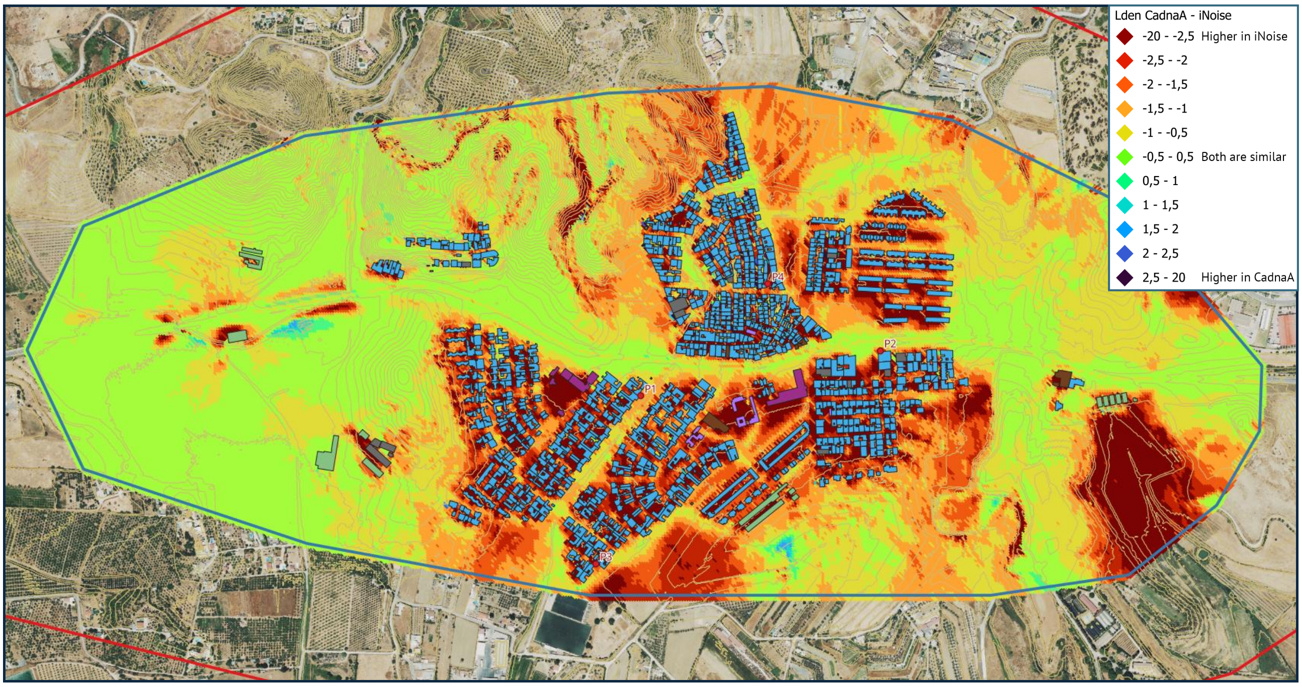

Figure 5. Heat map of L_{den} CadnaA - iNoise

4.2 Population exposure

Noteworthily, deviations in population exposure between both applications were detected to be in the opposite direction: CadnaA obtains higher exposure levels than iNoise, as seen at the Figure 6, with more people considered to be in the higher isophonic ranges.
Day, evening and night exposure levels follow the same trend, so for brevity only L_{den} exposure is shown here.
As stated before, the radically different approaches between both applications to assess population exposure might be the reason of these deviations: independent façade receivers in iNoise vs grid results with building evaluators in CadnaA, and the usage of different calculation methods for single and multi-dwelling façades in iNoise vs a single method for all dwelling types in CadnaA.

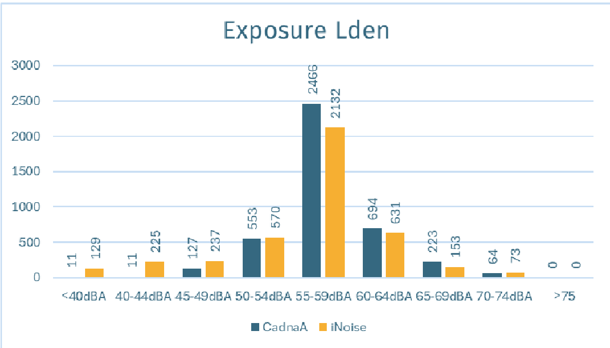

Figure 6. L_{den} exposure levels

5. DISCUSSION

The ISO 17534 is a huge step in harmonising the results obtained by diverse implementations of sound propagation modelling implementations in general, and the CNOSSOS-EU method in particular. These quality tests are a crucial advance in noise modelling across Europe. However, the question on disparities in the results obtained by different applications still remains, as several studies on the matter keep reaching to the same conclusions: fulfilling the test cases considered by the ISO 17534 quality controls is not enough to always achieve consistent results with different CNOSSOS-EU implementations [5][6].
While the ISO 17534 quality control focuses on propagation, reflections, diffractions, abatement, terrain, obstacles, etc., sometimes the divergence in results have other causes: disparities in data importing and management flows, model tools and optimisers, data item implementation, terrain model triangulation algorithms, software licence limitations, grid design and requirements, optional methods or parameters considered, and other hard to homogenise nor reconcile software design decisions taken by the developers of these applications.
No unique and definitive solution can be proposed here, but suggestions and wishes.
Adding implementation directives to the current test cases should improve the homogenisation of CNOSSOS-EU implementation and reliability.
Moving model information between applications should not be this hard. A data exchange file format for acoustic modelling would be of high interest for administrations, the main client for noise maps, and would help to ascertain deviations between implementations with more ease.
While acoustic modelling has had remarkable progression in the last 20 years, and CNOSSOS marked a critical step in the best direction, there is still a fascinating road ahead.

6. CONCLUSIONS

iNoise® and CadnaA® are fully valid implementations of the CNOSSOS-EU method, as they are certified to fulfil all ISO 17534 requirements, as many other solutions available.
While these conclusions are only applicable to this case scenario, deviations in results were found, which was not surprising as this is a recurrent situation every time the results of two or more implementations for the same model are compared.
While statistical analysis provides conclusions on the importance and relevance of deviations in results obtained by several implementations of CNOSSOS-EU, heat maps offer insight on the reasons behind those deviations.
For the case scenario of this study, iNoise calculated a higher propagation of sound than CadnaA, and according to the heat map, the cause of these deviations might be in how each application deal with obstacles and terrain. On the other hand, CadnaA considered population exposure to be higher than iNoise, and in this case the reason behind it might be CadnaA has no option to employ different calculation methods for single and multiple dwellings.

7. ACKNOWLEDGMENTS

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