inter.noise
27-30 AUGUST HONG KONG 2017

Technical aspects of the implementation of Directive EU 2015/996 into noise mapping software

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ABSTRACT

The Environmental Noise Directive requires the mapping of the noise following common noise assessment methods. These methods have been adopted under Directive EU 2015/996 (3) based upon the DG JRC Reference Report published in September 2012 (4) and their use starting from the fourth round in 2022 is mandatory. Any new implementation of a method is done by its inclusion within noise mapping software in a consistent manner meaning that different software products produce the same results for the same test situations. On the other hand, the new road method according to Directive EU 2015/996 includes the input of extended data, such as five vehicle categories or user-defined road surface absorptions. Gathering this data can be a challenge in those Member States where no previous databases exist.

This paper discusses the implementation of the Directive 2015/996 calculation methods into a noise mapping software platform including its technical and operational aspects as well as the most important elements that must be taken into account in order to meet the requirements of the applicable quality standards.

Keywords: Strategic Noise Mapping, CNOSSOS-EU, Directive 2015/996EC I-INCE Classification of Subjects Number(s): T7.7

1. INTRODUCTION

Directive 2015/996 EC (3) set out the new CNOSSOS-EU common methods for the calculation of industry noise, road traffic noise, railway noise and aircraft noise. These methods are based on several projects as well as other calculation standards. The new methods will be used as mandatory by the European Member States from the fourth round of strategic noise mapping in 2022.

Therefore, the CNOSSOS-EU methods have already been included within commercial noise mapping software. In order to implement noise calculation methods in a consistent manner, there are a number of aspects considered under the framework of the quality assurance for noise software products (5) which need to be addressed by the different involved parties. First, the developer of the method must deliver a complete description of the equations in such a way that there is one interpretation possible so developers would implement the method in the same way into different software. Secondly, developers must prove the compliance with the method by means of a declaration of conformity, and document any variation or addition to the method and how the results may be influenced. Finally, the end users must confirm the compliance with the method by applying test case files and investigate the effects of modifying the reference configuration of calculations. Moreover, the end user must correctly convert the data used in former calculation methods in case the collection of new data is not possible.

2. CNOSSOS-EU ROAD MODEL DESCRIPTION

As an example, this section presents the implementation of CNOSSOS-EU Road model method into a software (1). The traffic flow is represented by a source line which is segmented into single point sources at 0,05m above the road surface for all vehicle classes.

The general equation is:

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$$L_{W',eq,line,i,m} = L_{W,i,m} + 10 \times \lg\left(\frac{Q_m}{1000 \times v_m}\right) \quad (1)$$

Where the exponents Q_m is the steady traffic flow of vehicles of category m per hour and v_m is the average speed in km/h.

There are two sources of noise: propulsion noise, produced by the drive line (engine, exhaust, etc.) of the vehicle, and rolling noise, caused by the road – tire interaction. The propulsion noise is calculated by equation (2):

$$L_{WP,i,m} = A_{P,i,m} + B_{P,i,m} \times \left(\frac{v_m - v_{ref}}{v_{ref}}\right) + \Delta L_{WP,i,m} \quad (2)$$

Where the coefficients $A_{P,I,m}$ and $B_{P,I,m}$ are given in octave bands for each vehicle category and for a reference speed v_{ref} of 70 km/h.

On the other hand, the rolling noise is calculated from (3):

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} \times \lg\left(\frac{v_m}{v_{ref}}\right) + \Delta L_{WR,i,m} \quad (3)$$

The coefficients A and B have a one-to-one relationship with the existing vehicle categories considered by the standard for propulsion and rolling noise emission. All vehicles are grouped in five categories but there should be the possibility of including new categories as far as the average European fleet of vehicles may change in the future:

Table 1 – CNOSSOS-EU vehicle categories

CNOSSOS-EU – vehicle categories	Description
Light motor vehicles	Passenger cars, delivery vans <=3.5 tons, SUVs, MPVs including trailers and caravans
Medium heavy vehicles	Medium heavy vehicles, delivery vans >3.5 tons, buses, motorhomes, etc. with two axles and twin tire mounting on rear axle
Heavy vehicles	Heavy duty vehicles, touring cars, buses, with three or more axles
Powered two-wheelers	Two-, Three-, and Four wheel mopeds
Motorcycles	Motorcycles with or without sidecars, tricycles and quadricycles

3. IMPLEMENTATION INTO NOISE MAPPING SOFTWARE

The second step of the ISO 17534 (5) involves software developers for the implementation into a software platform. The actions undertaken by developers are to review the documentation in detail looking for mistakes or unclear expressions. Then the implementation into the software must be done, informing about any variation or additions to the method. Finally, developers should run test cases using the reference configuration and certify the conformity of the implementation.

3.1 Traffic flow and vehicle categories

The way the traffic data is entered in some software platforms (1), uses – as the majority of road noise standards do – a scheme based on hourly overall traffic and percentage of heavy vehicles (two vehicle classes). CNOSSOS-EU considers five vehicle classes which are expressed by total number of vehicles and the percentage of each heavy and motorcycle category. Figure 1 shows the edit dialog of a road. The Number of vehicles / hour refers to the total amount of all classes; the % heavy vehicles 2+3, refers to the total number of vehicles / hour. Finally, the % heavy trucks 3 in 2+3, refers to the percentage of heavy vehicles 2+3 being assumed as 100%. The same approach for the % of motorcycles 4a+4b and 4b in 4a+4b applies.

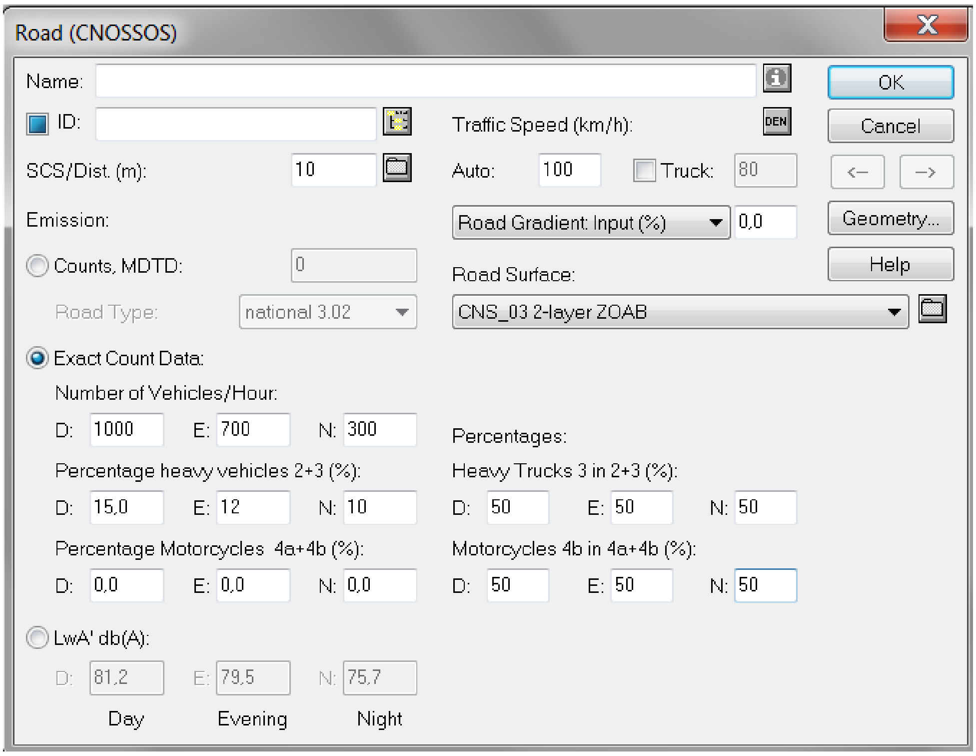

Figure 1 – Road edit dialog in the software1. The percentage of heavy trucks 3 in 2+3 is 50% for the day period. Therefore, there is a 7.5% of category 3 as the percentage of heavy vehicles 2+3 is 15%. On the other hand, as the percentage of motorcycles 4a+4b is 0, there are no motorcycles in 4a and 4b.

Additional vehicle classes can be included into the fifth category “open category” in order to manage situations where the vehicle fleet varies away from the average fleet. Figure 2 shows the general settings dialog where such new classes can be defined.

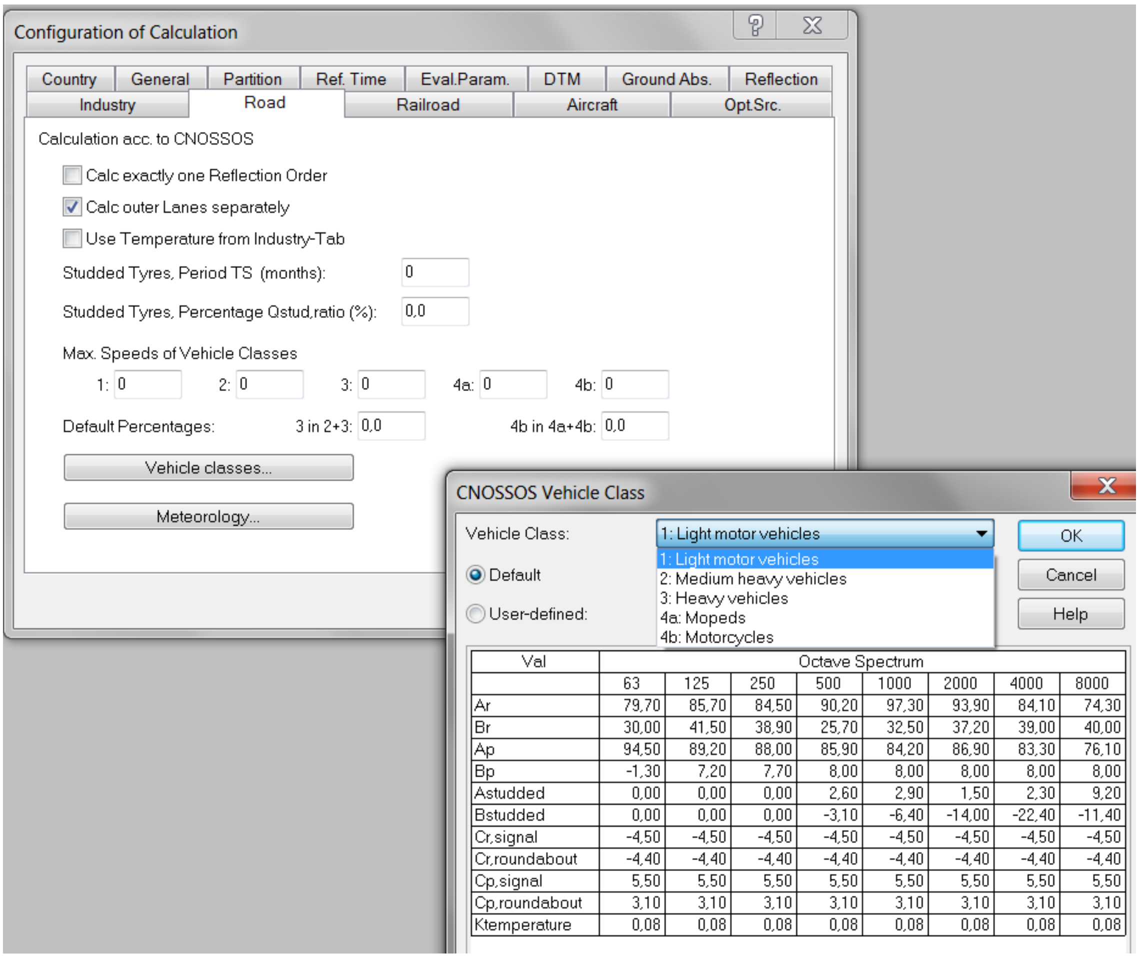

Figure 2: General settings dialog in the software (1), and Vehicle class dialog with the by-default correction values

For light, medium and heavy motor vehicles (categories 1, 2 and 3), the total sound power corresponds to the energetic sum of the rolling and the propulsion noise. For two-wheelers (category 4), only propulsion noise is considered. For all categories, with speeds less than 20 km/h the sound power level as for v m =20 km/h is used.

3.2 Source geometry

In CNOSSOS-EU, a road with multiple lanes can be replaced in the calculation alternatively:

- By a number of source lines placed in the center of each lane, or
- By a single source line in the middle of a two-way road, or
- By one source line per carriageway in the outer lane of multi-lane roads.

The software applies the alternative 3 by default. As the gradient correction is based on a “per lane approach” means that in the case of a bi-directional traffic flow, it is necessary to split the flow into two components and correct half for uphill and half for downhill. Therefore alternative 1 or alternative 2 would be needed. Figure 3 illustrates the different modelling situations within the software:

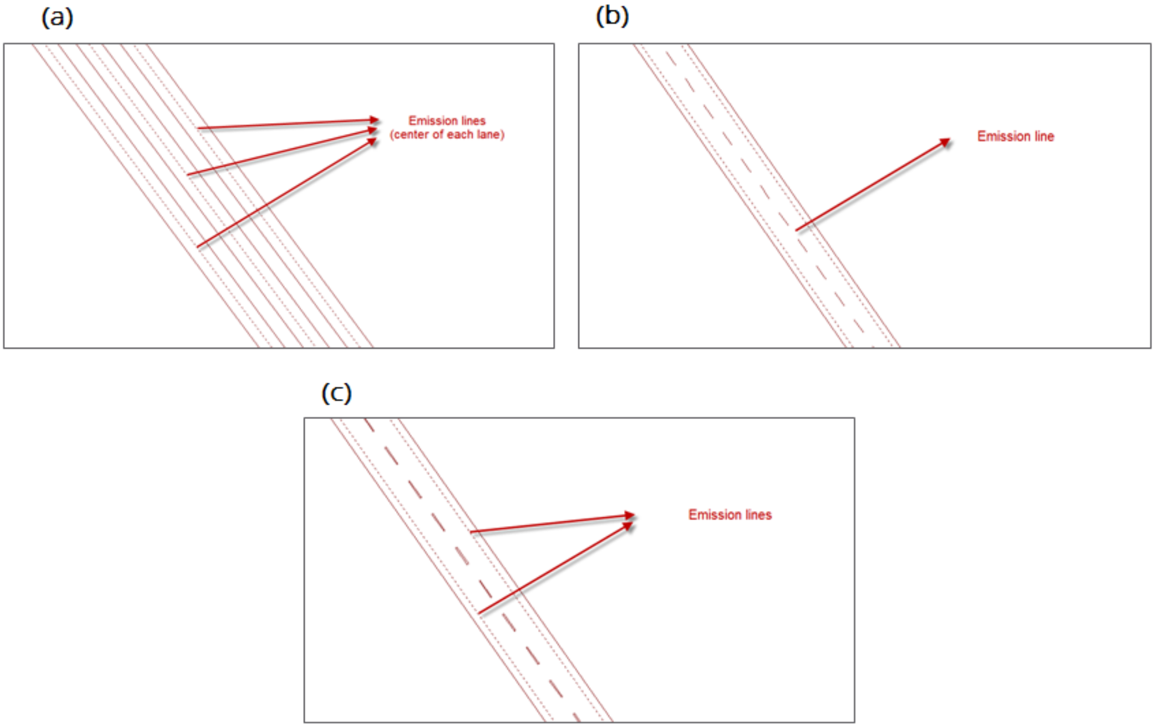

Figure 3: Different modeling situations for a multi-lane road. (a) multi - source placed in the center of each lane (b) source placed in the middle of a two-way road and (c) one source line per carriageway in the outer lane of multi-lane roads

3.3 Speed correction

In CNOSSOS-EU there are two types of maximum speeds: the maximum legal speed of the vehicle category and the maximum legal speed of the road or a road section. If real measurement data is not available, it is accepted that the lower of both is suitable for strategic noise mapping purposes and therefore, the lower of both is applied.

Maximum traffic speed for each category can be entered in the general settings dialog (Figure 2) while the road section legal speed is specified in the road edit dialog for light and – optionally- for heavy vehicles separately (in km/h). The speed limit entered for "Autos" will be considered for autos and motorcycles while the speed limit entered for "Trucks" - if any - will be considered for medium and heavy trucks. With the limit entered just for "Autos" (i.e. option "Trucks" deactivated) the value applies to all types of vehicles (i.e. no intrinsic speed limit for trucks). Consequently, there is no road-specific speed limit for motorcycles. However, a vehicle class specific speed limit for motorcycles can be entered on the general settings dialog (Figure 2).

3.4 Effects of the road surface

CNOSSOS-EU assumes a virtual reference surface, consisting of an average of dense asphalt concrete 0/11 and stone mastic asphalt 0/11, between 2 and 7 years old and in a representative maintenance condition. The road surface correction accounts for the effect on the rolling noise of road surfaces different than the virtual reference surface:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_m \times \lg\left(\frac{v_m}{v_{ref}}\right) dB \tag{4}$$

Where $\alpha_{i,m}$ is the spectral correction in dB at reference speed v_{ref} for category m (1, 2 or 3) and spectral band I and $\beta_{i,m}$ is the speed effect on the rolling noise reduction for category m (1, 2 or 3) and is identical for all frequency bands.

The road surface affects propulsion noise emission as well:

$$\Delta L_{WP,road,i,m} = \min(\alpha_{i,m};0) dB \quad (5)$$

Equation (5) means that absorbing surfaces decrease the propulsion noise, while non-absorbing surfaces will not increase it.

The CNOSSOS-EU specific road surfaces work within a variable speed validity range. On the other hand, CNOSSOS-EU does not specify how to handle speeds lower the listed minimum speeds, but higher than the general lower speed limit of 20 km/h. In the same way, it does not specify how to handle speeds higher the listed maximum speeds. In the software implementation, therefore, the road surface corrections are applied irrespective of the speed for the time being.

4. ASSESSING THE UNCERTAINTY BY USING DIFFERENT CONFIGURATION SETTINGS

In the final step of the ISO 17534 (5) the users play an important role undertaking extra tasks in order to close the cycle of the quality process. One of these tasks is to run calculations of the test cases, applying the reference configuration. This way, users can give feedback about the correct implementation of the standards into the software.

On the other hand, as any software provides the user the ability to modify the reference configuration – which makes sense especially for large projects, where the reduction of the calculation time is critical -, users should investigate the possible deviation in the calculation results produced due to the application of acceleration techniques and configurations different than the reference one. As an example, the projection of line sources is presented below. In CNOSSOS-EU line sources are segmented with each segment being replaced by a point source. The way the different software products determine the segments is different and in some cases special techniques are applied in order to improve the results. In the test case shown in figure 4, the road is divided into sections by applying a raster factor. Therefore, depending on the distance between the source and the receiver a different number of sections are created.

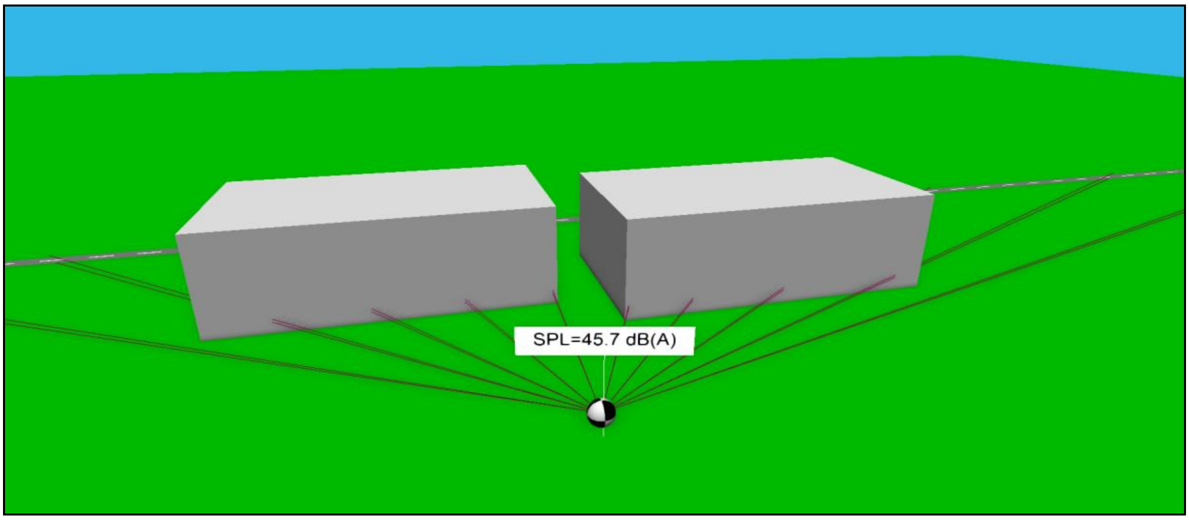

Figure 4 – Calculation of the test case at a receiver (without projection technique). The rays are created starting from the center of each road section

But, in fact, not all partial areas, which are included in the calculation with the paths of the two rays, are shielded by the building. Figure 5 shows the ray paths created from the road to the receiver point by following the standard segmentation rules. But, in fact, there is a direct view between the road and the receiver through the gap between the two buildings however that section is not accounted for the calculation. The resulting Sound Pressure Level (SPL) will be too low in the present example.

With the projection technique, prior to the segmentation of sources, a pre-partitioning for the road occurs subdividing the source into screened and unscreened parts. In a second step both types are segmented separately based on a distance criterion. The resulting Sound Pressure Level is higher and in this case more correct than without projection.

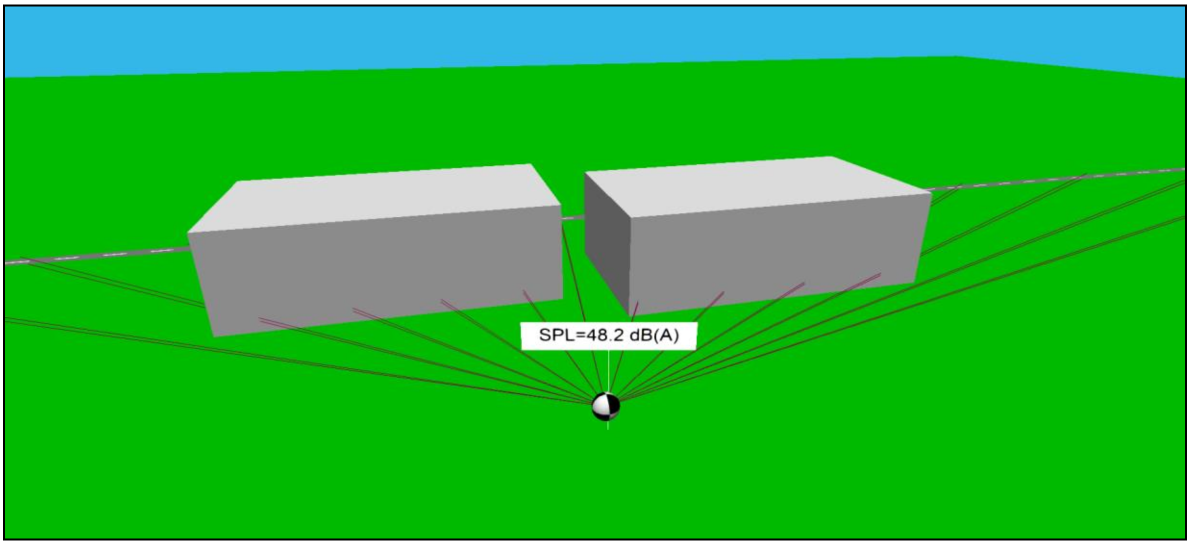

Figure 5: Calculation of the test case at a receiver (with projection technique). The new segmentation now takes into account the direct view between the road and the receiver point

As it has been demonstrated, the application of a different configuration leads to different results. The quality assured implementation of CNOSSOS-EU standards requires the software developer to prepare a statistical analysis tool to check the effect of any configuration settings the user may alter from the reference configuration and therefore could affect the calculated results.

In Figure 6 an example of a statistical tool is presented: a selected number of receiver points is distributed statistically inside this area taking into account some requirements about minimum distance to sources and reflecting objects. The levels are calculated once with the reference configuration settings and once with the altered configuration setting by the user. After both calculation runs, level differences are analyzed and the 0.1 and 0.9 percentiles define the interval of deviations caused by this setting. Mean and Standard Deviation are also calculated and delivered.

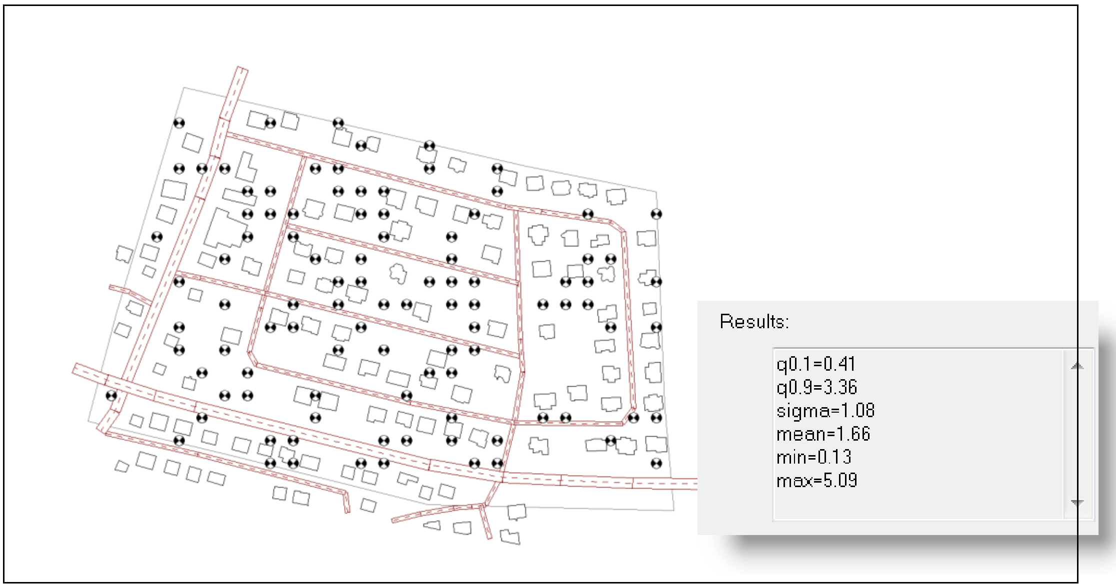

Figure 6: Receiver points distributed automatically according to standardized requirements and results of the statistical analysis

The result of such an analysis comprising generally about 100 or more receivers is presented as an interval specifying the uncertainty of results due to the deviation of the software configuration from reference settings.

5. CONCLUSIONS

An overview of the aspects of the implementation of CNOSSOS-EU into a noise software platform in a consistent and quality assured manner has been presented. First, the noise calculation method has been implemented into commercial software in a quality assured manner, which means that the developers of the method prepared a technical report addressing any unclear aspects of the method as well as test cases used by the software developers to certify the implementation and provide a Declaration of Conformity.

The end users may then check the correct implementation of the method in software using the test cases published by the developers of the method, and the reference configuration of the software provided by the software developers. The end user will also be able to undertake analysis to assess the uncertainty in the results introduced by any software acceleration techniques used.

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