MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Do We Have To Choose Between Fast Or Accurate Noise Modelling?

Miklós Márkus[1]
FONOR Environmental Protection and Occupational Safety Ltd.
20-22 Pósa Lajos Street, Budapest, Hungary, H-1149

Bettina Takács[2]
FONOR Environmental Protection and Occupational Safety Ltd.
20-22 Pósa Lajos Street, Budapest, Hungary, H-1149

ABSTRACT

Noise modelling can be either very simple (and fast) or very complex (and accurate). Besides the benefits, there are also dangers for both. The purpose of my presentation is to analyse the extremes of model construction using "SWOT-like" analysis.

The complexity of the noise model is determined by the aim of the task and the accuracy of the source data. If we are preparing an urban-scale model for strategic noise mapping, we move towards simplification. However, if we are preparing a noise control action plan for an industrial facility, or we have to predict the expected impact of an investment, the simplification comes with high risk and uncertainty. Therefore, we need to look at not only the aim of the task, but also the method of producing the necessary data.

At the same time, the complexity of the model increases the number of objects, the calculation time and the possibility of errors. Is there a reasonable limit to the complexity of modelling, after which only the calculation time is increasing, but accuracy is not? Can simplification lead to mistakes and the increase of uncertainty? In the course of the presentation, I discuss numerous practical case studies covering the above questions.

Keywords: Industrial Noise, Noise Model, Case Study
I-INCE Classification of Subject Number: 55, 56, 76

[1] markusmiklos@fonor.hu
[2] takacsbettina@fonor.hu

1. INTRODUCTION

In recent years, many presentations were dedicated to the analysis of harmonized CNOSSOS-EU (Common NOise aSSessment methOdS in the EU) calculation method [1] at international conferences. However, many of these examinations were concerned about detectable differences in the calculation process of road traffic noise or railway traffic noise. In our presentation, we focus on a certain aspect of industrial noise modelling: issues regarding the complexity of the model.

Many studies examined differences between the CNOSSOS-EU calculation method and certain international or local standard calculation methods [2] [3]; meanwhile also comparing or validating the calculation method [4]. Thus, for examination purposes, we make the modelling issue as independent from the calculation method as we can, and we concentrate on the model structure.

Industrial facilities include many noise sources; also, there are a lot of objects present in their area which influence sound propagation. Nonetheless, it is nearly impossible to model all objects of an industrial facility with noise modelling software in use today. Modelling of obstacles like pipe bundles, pipe bridges, open technology units or tanks at high position can only be implemented in a limited way for the time being.

On the other hand, in case of certain types of industrial facilities (e.g. open technology oil or chemical industry plants), where these obstacles are missing from the model, noise propagates on the industrial area without attenuation, diffraction or reflection, and factors influencing the actual noise level of sources cannot be calculated. So in case of models which are not detailed enough, usually a higher sound pressure level is calculated at areas far from the plant than what can actually be measured in reality [5].

2. RECOMMENDATIONS

2.1 CNOSSOS-EU

There are few recommendations which make suggestions or formulate aspects in relation to the complexity of the model. The chapter concerning industrial noise in CNOSSOS-EU [6] also makes recommendations for creating the model, and also for the general rules to be applied in defining the number of point sources to be used. The CNOSSOS-EU calculation method is widely known and is a peculiar type of methods presented here, so it is used as a reference in our comparison.

An important aspect is that the CNOSSOS-EU formulates its recommendations for the construction of a large-scale (urban) strategic model. As it states: the industrial sources are of very variable dimensions, therefore, it is necessary to use an appropriate modelling technique for the specific source under assessment. In practice, the calculations of the noise effect are always based on point sources. The CNOSSOS-EU method applies the well-known distance formula to determine the number of necessary point sources: line or surface sources where the largest dimension is less than 1/2 of the distance between the source and the receiver can be modelled as single point sources.

However, in case of a detailed industrial model, there are situations when this simplification can be misleading. In case of different source types, when the effect of a planned noise source is only known at a far-field point (e.g. limit value), then we get significantly different result in a near-field point (e.g. reference point of warranty measurement).

However, the CNOSSOS-EU method also secures aspects which are related to the accuracy of the noise model; so among other things, it also discusses that doubling the number of sources over the source area (in all dimensions) may not lead to a significantly better result.

Another deduction of the method originating from large-scale modelling is that if certain source data is missing and therefore replaced with assumed or somewhat uncertain information, in many cases the resulting industrial noise assessment may not be compromised because the total error is reduced due to many sources contributing to the calculation simultaneously.

2.2 WG-AEN Toolkit

The recommendation (Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure) [7] of the European Commission Working Group Assessment of Exposure to Noise (WG-AEN) is also widely known. Among other things, in its Chapter 4 (Toolkits of solutions relating to specific challenges), it gives tools for handling various situations where the sound power level of the noise source cannot be determined for some reason. It categorizes the recommended tools into three aspects: complexity, accuracy and cost. Based on these aspects, the most complex, most accurate and most expensive method of determining sound power level is the measurement (ISO 8297); meanwhile the least complex, accurate and expensive method is the application of predefined sound power levels.

It is highlighted once again that the solutions of the toolkit can only be used in case of the construction of a large-scale (urban) model. ISO 8297 specifies the engineering method for the determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels; so this method cannot be used for measuring individual noise sources, determining their sound pressure levels, modelling them in details and examining their effects.

3. THE EXTREMES OF COMPLEXITY

3.1 From strategic noise mapping to noise control action plan

The complexity of the noise model is basically determined by the aim of the task. If we are preparing an urban-scale model for strategic noise mapping, we move towards simplification. However, if we are making a noise control action plan (for an industrial facility), or we have to predict the expected impact of an investment, the simplification comes with high risk and uncertainty. At the same time, the complexity of the model increases the number of objects, the calculation time and the possibility of errors.

As we have seen, methods concerning the construction of strategic noise mapping always lead to simplification (for obvious reasons). This entails that the strategic model of industrial areas includes few objects and few noise sources. This leads to bigger uncertainty.

For absolutely obvious reasons, we cannot aim to expand a model already including tens of thousands of objects with ten thousands of additional objects if a single plant is constructed. So in case of strategic noise modelling of industrial noise, the model must be simplified, or else the calculation time will show a significant, but needless increase.

At the other end of the range, there is the highly detailed model necessary to prepare noise control action plans. In these models, we aim to model noise sources individually, as we have to determine the dominant noise sources in the plant, priorities of noise control actions and also the individual noise reduction requirements. Our objectives also may include shutting off certain noise sources or source groups and analyzing their effects separately. For that, every (dominant) source has to be indicated in the model.

In case of noise control planning tasks it is useful if there are objects in the model which have to be taken into consideration during the design process of the noise reduction solution (e.g. sound barrier walls). According to our experiences, the 3D view of the noise model is a major contributor during the first rounds in plant discussions about noise control actions. But in order to make surrounding objects viewable as well alongside noise sources, these objects must be built with appropriate accuracy.

3.2 Customer focused modelling

There are aspects (not related to noise protection) based on which the details of the model can be further enhanced. I call these aspects “customer focused modelling”. In this case, with the noise model, we wish to correspond to customer requirements (real or perceived) which do not serve noise protection or professional purposes anymore.

In these cases, we depict objects on the model which help navigation, but are irrelevant for the calculation of sound propagation (e.g. columns, platforms, machine bases etc.). This also includes the coloring of buildings or tanks and also drawing the borderlines of service roads, which can be a meticulous work on a huge industrial area, but it has no benefit for us. Goals of the customer focused modelling can be:

1. Plant designers and decision-makers would like to understand the model better (they would like to have a more comfortable way of looking at the model), and they wish to identify certain technological units and equipment more easily. In this way, there is no need for further explanations about what we see. Also, a detailed model makes further noise control action planning collaboration possible.

2. We would like to impress the customer. According to our experiences, if presented well, the model can also be used as an advertisement-like communication tool. Customers rarely look at a three-dimensional model with the eyes of a professional. So when the result of the plant modelling task is presented, a model which is closer to reality and is built more in a more detailed way than professional requirements can hold a significant value.

3. In many cases, our customers also aim for a spectacular model. If they have to present the modelling project result to an absolutely non-professional audience (e.g. people, political decision-makers or plant management), a model which is closer to the reality and is easy to understand can be effective.

4. Technology designers are now accustomed to three-dimensional designer tools (3D CAD, Navisworks, Solidworks etc.), which include even the smallest bolt of the planned plant, in incredible details. However, compared to 3D CAD files serving as source data, the noise model is still significantly simplified. Based on our experience, it is sometimes needed that the completed noise model be as close to the source file as possible (even if only with the applied coloring).

The capabilities of the noise modelling software determine the limits of preparing a complex model which is in compliance with the above-mentioned goals (and is well beyond professional aspects). Currently used modelling software are indeed not prepared for drawing objects in which the complexity is similar to 3D CAD modelling. For example, it is not easy to build the detailed view of open technology plants in a modelling software (because of tanks in high positions, floating reflective surfaces, horizontal containers, intricate roof construction). So currently, we are continuously pushing the limits of the modelling software (and often exceed it with unique solutions).

3.3 Planning in advance

It is nearly impossible to switch from a strategic model to a detailed noise control planning or technology development model. Based on our experiences, strategic models cannot be applied to other tasks because of high degree of simplifications. In case of more complex models, usually the model has to be rebuilt from the base; few plant objects can remain in their original formats and source data must be produced again with a more accurate method.

Because of this, we have to know beforehand that in the future, what purpose shall be served by the noise model we build. It is possible that for now, we only calculate the environmental noise pollution of the plant or designate its range; but if we need a more detailed analysis in the future, we have to implement the task with a completely different attitude.

4. LEVELS OF COMPLEXITY

4.1 Producing source data

The accuracy of the noise model is also determined by the accuracy of the source data. Therefore, we need to look at not only the aim of the task, but also the method of producing the necessary data. If we are needed to achieve some accuracy, we must demand the correct source data (and accuracy should be considered not only in noise data but also in geometric data).

According to Chapter V.2.3. of CNOSSOS-EU, each relevant source should be measured to obtain accurate sources and noise maps. There are a considerable number of standards and guidelines on measurement methods for industrial noise sources.

Unfortunately, the methods described in the standards are often not specifically intended for providing input data for noise mapping purposes, so there may be certain shortcomings in using a specific standard for that purpose even if, in principle, it is applicable to the source(s) in question. On the other hand, in some cases the described methods can be improved by simple means to yield the desired information even if they were not originally designed to provide that information [6].

In our practice, this situation usually occurs when we evaluate the source according to the ISO 3746, but we calibrate the model according to the ISO 9613-2 with results measured at the reference points. However, analyzing the differences between sound power level calculation methods and sound propagation calculating methods applied by noise modelling software could be the subject of another presentation.

During producing source data, we obviously obtain more accurate data at existing industrial sites, as in this case, data can be determined with measurement. In case of planned sites however, uncertainty of source data is always bigger. This is why that in our practice, even in case of design tasks, we prefer if there is an actual source to be measured which is similar to the planned noise source (under real operation circumstances).

4.2 Complexity of the model in relation to source data

In the table below, we evaluate source data based on our experience, depending on model complexity, accuracy and the cost (time) of source data production. In relation to costs, in some cases, we have not only taken into account the resource requirements of source data production, but also the time requirement necessary for further working with the given source data (modelling).

Table 1. Type of source data

Type of source data	Complexity	Accuracy	Cost
A-weighted Sound Pressure Level (SPL)*	●	●	●
SPL in octave or 1/3 octave band levels*	●●	●●	●
A-weighted Sound Power Level (PWL)	●	●	●●
PWL in octave or 1/3 octave band levels	●●	●●	●●
SPL* & PWL in 1/3 octave band levels	●●●	●●●	●●●
SPL* & PWL in 1/3 octave with directivity	●●●●	●●●●	●●●●

* the measurement distance is required (e.g. SPL 1m)

Table 2. Method of source data production

Method of source data production	**Complexity**	**Accuracy**	**Cost**
Default values [7]	●	●	●
Calculated back from noise limit*	●	●◖	●●
Public database	●●	●●	●●
Software internal database	●●	●●	●
Manufacturer catalogue data	●●	●●◖	●●◖
Measured SPL	●●●	●●●◖	●●●
Measured SPL & Calculated PWL	●●●	●●●●	●●●●

* nationally defined permissible sound level

Table 3. Method of surface model (DSM) production

Method of DSM production	**Complexity**	**Accuracy**	**Cost**
Estimation based on photos	●	●	●●
2D layout with height data	●●	●●	●
On-site measurement (LDM)	●●	●●	●●
2D view & sectional plan with height data	●●●	●●●	●
Photogrammetric survey	●●●	●●●	●●
3D CAD (e.g. Navisworks, Solidworks)	●●●●	●●●●	●◖
3D Laser Scanning	●●●●	●●●●	●●●●

Table 4. Method of terrain model (DTM) production

Method of DTM production	**Complexity**	**Accuracy**	**Cost**
No terrain model	●	●	●
Digitization of topographic map	●●	●●	●●
Processing of orthographic aerial photos	●●	●●◖	●●
On-site geodetic survey	●●●	●●●	●●●
Airborne Laser Scanning	●●●●	●●●●	●●●●

Table 5. Complexity of objects

Objects	**Complexity**	**Accuracy**	**Cost**
Large buildings (blocks)	●	●	●
Building & structures (with roof shapes)	●●	●●	●●
Tanks, pipelines, pipe bridges, bundles	●●●	●●●	●●●
Columns, pods, walls, diffusers etc.	●●●●	●●●●	●●●●

4.3 The effect of model complexity on the results

Below we present a case study showing how changing the complexity of the model affects sound pressure levels calculated for the evaluation points around the plant. As we mentioned in the introduction, in case of models which are not detailed enough, usually a higher sound pressure level value is calculated at areas far from the plant than what can actually be measured in reality [5].

We examined the following situations with continuously decreasing complexity by using the measurement-based model of an open technology chemical plant with no terrain model (flat surface). Its objects were built based on 2D CAD drawings and on-site measurements (Laser Distance Meter). Source data were set based on sound pressure levels measured in the near-field of sources. The model was calibrated with results measured on reference points (according to the ISO 9613-2). Calculations were performed according to the ISO 9613-2 reference method in the four cardinal points, at 300 m, and we made a grid calculation of 660 points. Results are averaged.

Table 6. The effect of model complexity on the results

Model complexity	**Number of objects**	**Calculation time [m:s]**	**Average SPL [dBA]**
1. Full detail model	**747**	**26:24**	**58,6**
2. Without columns, pods, walls, diffusers	**289**	**8:15**	**59,2**
3. Without tanks, pipelines, pipe bundles	**171**	**2:03**	**60,0**
4. Simplified sources (PWL in 1/3 octave)	**67**	**0:18**	**61,1**
5. Simplified sources (A-weighted PWL)	**67**	**0:09**	**61,0**
6. Without buildings	**37**	**0:04**	**62,0**

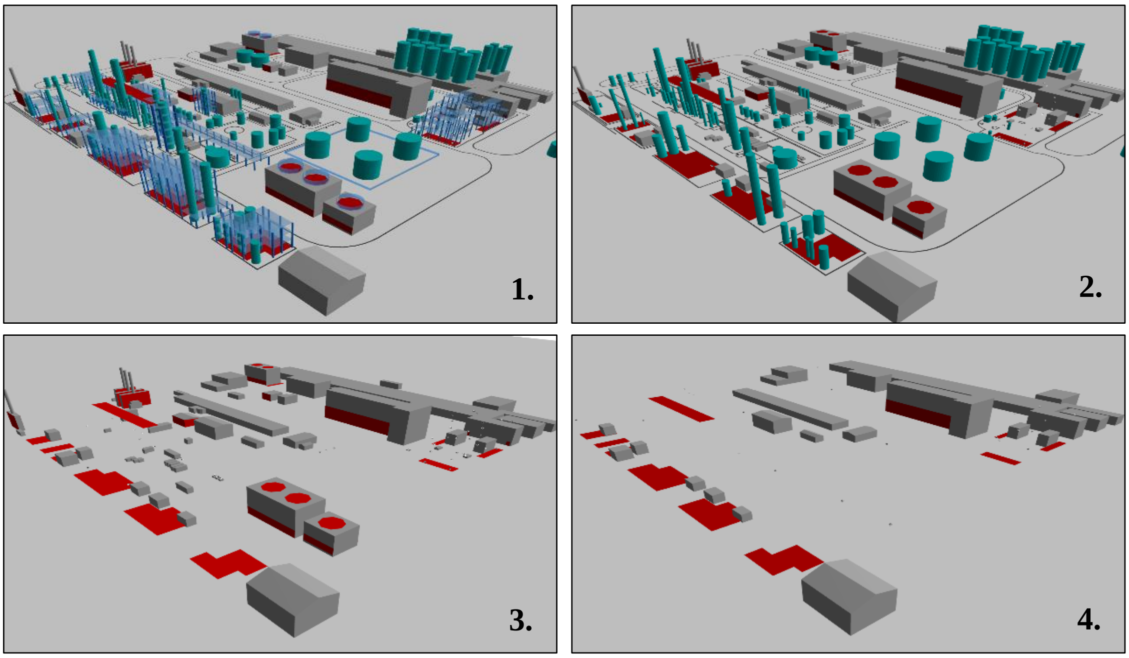

Figure 1. Different stages of model complexity

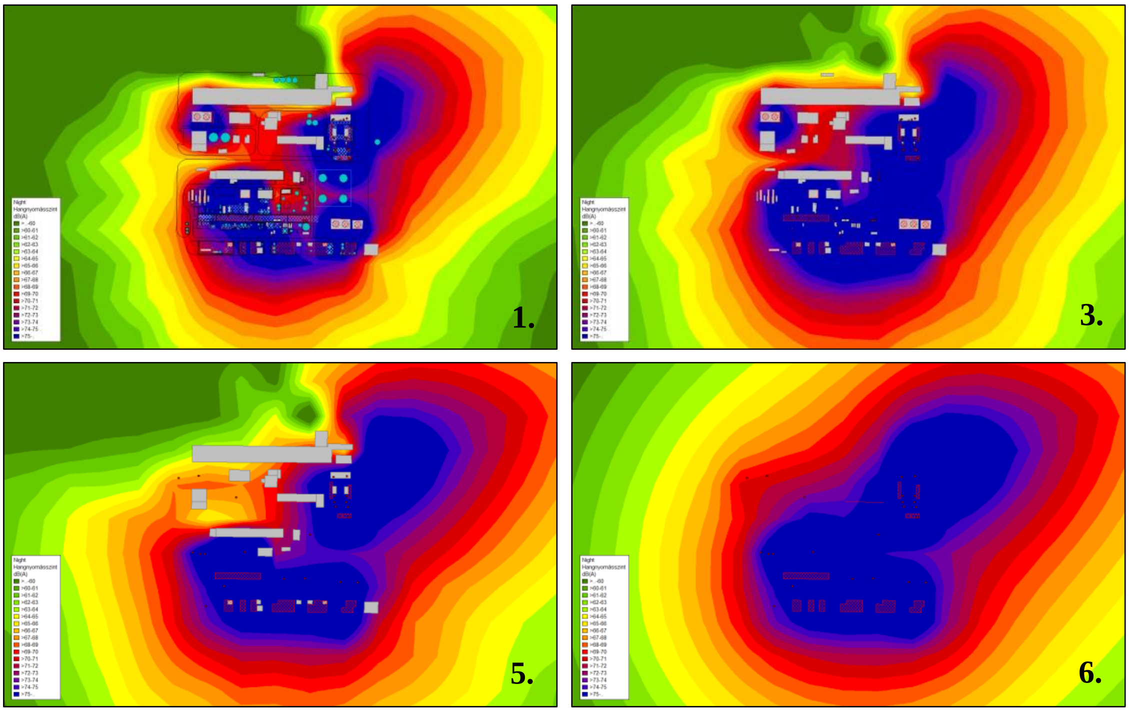

Figure 2. Grid calculation results of different model complexity

5. ANALYSIS OF THE COMPLEX MODEL

Below we summarize the advantages and disadvantages of complex industrial noise models (which are constructed in a highly detailed manner).

5.1 Advantages

- calculation results are more accurate, meaning the uncertainty of the calculation process is smaller
- the difference between calculated and measured results is smaller, as the model can be calibrated well enough by using the measurement results
- detailed modelling of ground attenuation and vegetation (if the proper calculation method is used) can significantly enhance model accuracy [4]
- in case of open technology (e.g. oil or chemical) plants, objects which are not buildings but have influence on sound propagation can be taken into consideration, thus calculation results will be more accurate
- the list of dominant noise sources is detailed, noise control priorities and reduction requirements can be determined source by source
- individual noise sources can be easily replaced, shut off, also the effect of unique noise reduction solutions can be modelled in a detailed form
- the environment of noise sources is as detailed as necessary for further planning of noise control solutions (e.g. for designing a sound barrier wall)
- a spectacular model stands closer to reality (or to a 3D CAD visualization), so it is much easier to sell the modelling project and its result
- plant managers, decision-makers (non-professionals) understand the model better (they have a more comfortable way of looking at the model), individual technological units, equipment, plant objects are more clearly identifiable, so it is not necessary to explain what we see

5.2 Disadvantages

- time (and human) resource requirement for preparing the model is significantly higher, considerably increasing project costs
- the possibility of failure is higher, and it is more difficult to detect them (e.g. software bugs or contradictions in calculation results)
- in order to build a model which pushes the limits of the modelling software, high professional knowledge and generally, higher level of IT knowledge is needed (e.g. highly skilled in the use of 2D graphics software)
- calculation time significantly increases, and in case of applying area source or line source, it can exponentially increase in relation to point sources
- in case of too many (e.g. hundreds of) noise sources, the model or the output data (e.g. dominant noise source list) may be difficult to handle (the model can even be overcomplicated)
- in case of larger industrial areas, the number of elements in the model can exceed tens of thousands which can make the work difficult (or even impossible in case of certain modelling software)

- certain modelling software make failures in case of calculations performed on very complex models or they can freeze at certain operations
- if the CNOSSOS-EU calculation method is used, modelling the ground and the vegetation in a detailed way leads to excessively different results than using ISO 9613-2 (or HMRI) [4]

6. CONCLUSIONS

Although I aimed to separate the analysis of model complexity from the applied calculation method, as we can see, the chosen calculation method also determines complexity. In case of using the CNOSSOS-EU, the more complex and detailed the model is (mainly regarding ground and vegetation), the higher the measure of failure will be compared to measurement results or to results determined with traditional calculation standards (e.g. ISO 9613-2). This means that by the time being, CNOSSOS-EU can be applied only in case of simple models when it is about large-scale, industrial noise sources.

Model complexity must be chosen depending on the aim of the task. So I think there is no middle ground when it is about choosing the appropriate complexity of modelling. In case of urban-scale, strategic modelling, the aim is still to simplify, but in case of action plans, complexity should be chosen as much as possibilities (costs) allow it.

6.1 The following type of process is recommended for strategic modelling

- **Type of source data:** A-weighted Sound Pressure Level (SPL) with measurement distance or A-weighted Sound Power Level (PWL)
- **Method of source data production:** Software internal database (if available) or public database
- **Method of surface model production:** Photogrammetric survey (urban scale) or 2D layout with height data
- **Method of terrain model production:** Processing of orthographic aerial photos
- **Complexity of objects:** Large buildings (blocks)

6.2 The following type of process is recommended for detailed plant noise modelling

- **Type of source data:** Sound Pressure Level (with measurement distance) and Sound Power Level in 1/3 octave with directivity
- **Method of source data production:** Measured Sound Pressure Level (e.g. ISO 9613-2)
- **Method of surface model production:** 3D CAD (e.g. Navisworks, Solidworks – if available) or 2D view plan & sectional plan with height data
- **Method of terrain model production:** Processing of orthographic aerial photos
- **Complexity of objects:** Building & structures with roof shapes, tanks, columns, pods, walls, diffusers

7. REFERENCES

1. Directive, "*EN. Commission Directive (EU) 2015/996 of 19 May 2015 Establishing Common Noise Assessment Methods According to Directive 2002/49/EC of the European Parliament and of the Council"* (2015)
2. Jarno Kokkonen, *"CNOSSOS-EU noise model implementation in Finland and experience of it in 3rd END round"*, Euronoise 2018, Crete (2018).
3. Tim Vergoed, Hans J.A. van Leeuwen, *"Evaluation and Validation of the CNOSSOS calculation method in the Netherlands"*, Euronoise 2018, Crete (2018).
4. Rob Witte, *"CNOSSOS and industrial noise"*, Euronoise 2018, Crete (2018).
5. Takahiro Hida, *"Engineering way to improve the accurate prediction of noise propagation in industrial plants using energy based method"*, Inter-Noise 2017, Hong Kong (2017).
6. Stylianos Kephalopoulos, Marco Paviotti, Fabienne Anfosso-Lédée, *"Common Noise Assessment Methods in Europe (CNOSSOS-EU)"*, EUR 25379 EN., Publications Office of the European Union, Luxembourg (2012)
7. European Commission Working Group Assessment of Exposure to Noise (WG-AEN), *"Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure"*, European Commission Environment DG Information Centre, Brussels (2007)