A COMPARATIVE ANALYSIS OF COMMON METHODS WITH INTERIM CALCULATION METHODS USED IN ACCORDANCE WITH EUROPEAN UNION LEGISLATION

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The assessment of noise for the sources specific to Directive 2002/49/EC is the obligation for all EU Member States. In 2007-2018 in Romania there was the obligation to assess the noise using the interim calculation methods specified in Directive 2002/49/EC. Since 2019 there is the obligation to use common noise assessment methods, called the CNOSSOS-EU, as a result of the applicability of Directive 996/2014/EU. The purpose of this paper is to analyze the significant differences between the noise interim computation methods and common noise assessment methods CNOSSOS-EU.

Particular attention was paid to the impact of the implementation of the CNOSSOS-EU common methods in Romania and to the contribution of authors to find an expedient method with the help of which is possible to find which type of mitigation is needed for the noise caused by the wheel and track interaction, taking into consideration the non-existence of the roughness noise measurements of the wheel and the rail in Romania

Keywords: noise maps; noise mapping; noise assessment; traffic noise, CNOSSOS-EU, rolling noise, roughness measurements, noise mitigation

List of abbreviations

EU	EUROPEAN UNION
EC	EUROPEAN COMMISSION
CNOSSOS-EU	Common Noise assessment Methods in Europe
IED	Industrial Emission Directive
NMPB	Nouvelle méthode de prévision du bruit
SRM	Standard berekening method
ECAC	EUROPEAN CIVIL AVIATION CONFERENCE

1. Introduction

The assessment of noise for sources specific to EU noise legislation [1] is the obligation for all EU Member States. In 2007-2018 in Romania there was an

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obligation to assess the noise using the noise interim computation methods (Interim methods) [1].

Since 2019, there is the obligation to use CNOSSOS-EU common methods, as a result of the applicability of the new EU directive [2].

A common framework for noise assessment methods (CNOSSOS-EU) was developed by the European Commission in cooperation with the EU Member States to be applied for strategic noise mapping, as required by the Environment Noise Directive (2002/49/EC). This framework represents a harmonized and coherent approach to address and assess noise levels from the main sources of noise (road traffic, railway traffic, aircraft and industrial) across Europe. It was based on state-of-the-art knowledge and resulted from an intensive collaboration, exchange of data and experiences via a formal process at both policy and scientific/technical levels [3].

The purpose of this paper is to analyze the significant differences between the interim methods and common methods CNOSSOS-EU and to assess the impact of the implementation of the CNOSSOS-EU common methods in Romania.

Directive 2002/49/EC regulates at EU level the noise assessment for four main noise sources, namely:

- Road traffic noise;
- Railway traffic noise;
- Air traffic noise;
- Noise of industrial plants covered by the IED [4] and ports.

For the noise sources listed above, the assessment is carried out through strategic noise maps for agglomerations with a population of more than 100000 inhabitants.

Also, in the case of traffic noise (road, rail and air), the assessment is carried out through strategic noise maps for major roads which has more than three million vehicle passages per year, the major railways which has more than 30000 train passages per year and major airports which has more than 50000 movements per year, both inside and outside agglomerations with more of 100000 inhabitants.

There are 20 agglomerations with more than 100000 inhabitants in Romania, around 3400 km of major roads, around 300 km of major railways and one major airport, so the use of the CNOSSOS-EU common methods will have a significant impact on the implementation of EU legislation in Romania [1], [2].

2. Differences between interim methods and CNOSSOS-EU methods

2.1. Road traffic

In the case of road traffic in 2007-2018 in Romania the noise assessment was made using the interim method which is the French method NMPB-ROUTES-1996 / XP S 31-133 [5], [6].

Table 1

Differences between Interim methods and CNOSSOS-EU methods for road traffic

	XP S 31-133 (NMPB) [4], [5]	CN CNOSSOS-EU [2]
Propagation model	NMPB	Based on NMPB
Traffic flow	4	3
Vehicle types	2	4 (in future 5)
Meteorological conditions	2	2
Frequency range	125-4000	64-4000
The height of the receiver point	>2 m	> 2 m
Atmospheric absorption	ISO 9613-2	ISO 9613-2
Ground factor	0 sau 1	0 sau 1
The effect of soil in favorable conditions	Derived from ISO 9613 -2	Derived from A_{sol} definition
Difference between propagation path lengths	Two conventional propagation conditions (homogeneous conditions)	Favorable conditions

The CNOSSOS-EU method for road traffic was developed based on the French method NMPB 2008 since the propagation part of CNOSSOS-EU is very close to NMPB 2008, but although they both methods combine the engine noise component and the rolling noise component the emission models of CNOSSOS-EU and NMPB 2008 differ in terms of formulation and input parameters.

The main differences between the CNOSSOS-EU method of road traffic and the Interim method are: several types of vehicles to be considered, coverage of the 64 Hz frequency band and the propagation path are considered to be favorable.

However, from the point of view of the impact of the implementation of the CNOSSOS-EU method for assessing road traffic noise in Romania, the main challenge will be to made the road traffic surveys within the agglomerations and of the road traffic census outside the agglomerations, taking into account four types of vehicles as required by CNOSSOS-EU common method for road traffic instead of two types required to Interim method.

Table 2

Differences between types of vehicles required for Interim methods and for CNOSSOS-EU methods used for road traffic

	CNOSSOS-EU	XP S 31-133 (NMPB)
Category 1	Light vehicles	Light vehicles
Category 2	Medium vehicles	Heavy vehicles
Category 3	Heavy vehicles	
Category 4	Motorized two-wheeled /three-wheeled vehicles	-
Category 5	Open category	-

As can be seen from Table 2 for the CNOSSOS-EU method there is additionally a category of two/ three-wheeled vehicles to be taken into account in the assessment of noise.

Also, if in the Interim method we had a heavy vehicle category, the CNOSSOS-EU method divided this category into two: medium vehicles (M2, M3, N2 and N3 approval categories) and heavy vehicles (M2, N2 with trailer, M3 and N3 approval categories).

The impact of considering four types of vehicles in Romania instead of two is the following:

- A database on road traffic (traffic studies and traffic census) should be created considering the four categories of vehicles;
- It is to be expected that in the case of major roads outside the agglomerations, where the percentage of heavy vehicles category from CNOSSOS-EU method it is significant, lead to an increase in the accuracy of the noise assessment compared to the use of the Interim method which did not distinguish between heavy vehicles and medium vehicles, all of which are considered heavy vehicles;
- It is to be expected that in the case of road traffic inside agglomerations, where percentage of medium vehicles of the CNOSSOS-EU method it is significant, lead to an increase in the accuracy of the noise assessment compared to the use of the Interim method which did not distinguish between heavy vehicles and medium vehicles, all of which are considered heavy vehicles.

There are different ways of obtaining data regarding the noise produced by road traffic, for example noise levels values obtained by on site measurements, values obtained by calculation using formulas and also the noise levels values obtained by modeling the area with a specialized software, and the best way is to use all these in order to compare the results [7].

This approach was the best when the noise assessment was made using the interim method but also is the best way when will used The CNOSSOS-EU method.

2.2. Railway traffic

In the case of railway traffic in 2007-2018 in Romania the noise assessment was made using the interim method, which is the Dutch national computation method, published in "Reken- en Meetvoorschrift Railverkeerslawaai '96 [8], commonly referred to as SRM II in the literature.

Table 3

Differences between methods and CNOSSOS-EU methods used for railway traffic Interim

	SRM II [6]	CN CNOSSOS-EU [2]
Noise source	Rolling noise, impact noise and traction noise	Rolling noise and impact noise
		Traction noise
	-	Squeal noise
	Aerodynamic noise	Aerodynamic noise
	Bridges	Additional effects (shunting yards and bridges)
Heights for noise sources	5 heights (0 m, 0,5 m, 2 m, 4 m, 5 m), impact noise at 0 m, rolling noise at 0 m and 0,5 m. traction noise at 4 m, aerodynamic noise at 5 m)	2 heights (0,5 m and 4 m), traction noise and aerodynamic noise at 0,5 m and 4m, other types of noise at 0,5 m
Directivity	Horizontal directivity	Corrections of horizontal and vertical directivity
Input data	10 category of trains	Complex source model depending on impact noise (crossings/ switches/ junctions), rolling noise (rail/wheel roughness), traction noise, squeal (radius), aerodynamic noise, directivity, bridges
Propagation path	Noise level (favorable propagation conditions using a distance correction factor)	Noise level under homogeneous and favorable conditions

From Table 3, it can be seen that the CNOSSOS-EU method for rail traffic differs substantially from the SRM II Dutch method.

The main differences with significant impact on noise assessment are the following:

- Traction noise is taken into account both at 4 meters height and at a height of 0.5 meters, unlike the Dutch method which takes into account the traction noise only at a height of 4 meters;
- Dutch method take into consideration five positions for noise sources while CNOSSOS-EU take into consideration only two positions for noise sources;
- The input data for the CNOSSOS-EU method are more complex, requiring a conversion of the input data used up to now for the SRM II;
- In the case of the CNOSSOS-EU method, in order to assess the noise, it is necessary to characterize and classify Romanian railway vehicles (trains), because those depends on several physical factors (rail roughness, wheel roughness, speed, etc.) or types of vehicles (diesel locomotive, electric locomotive, unlike the Dutch method that was developed for 10 predefined

categories of trains running in the Netherlands and for which corrections have been applied for use in the mapping of railway traffic noise in Romania [9].

Thus, the CNOSSOS-EU presents a simpler noise equivalent sources model by using only two heights for those, but more aspects are considered than at SRM II (squeal noise and two heights for traction and aerodynamic noise).

The equivalent sources include different physical sources which are divided into different categories depending on the generation mechanism, and are: rolling noise, traction noise, aerodynamic noise, impact noise (from crossings, switches and junctions), squeal noise and noise due to additional effects such as bridges and viaducts.

Two source heights are foreseen by the CNOSSOS_EU method at 0.5 m (source A), 4.0 m (source B) presented in Figure 1, and the equivalent sound power associated with each is distributed between the two depending on the specific configuration of the sources on the unit type [2].

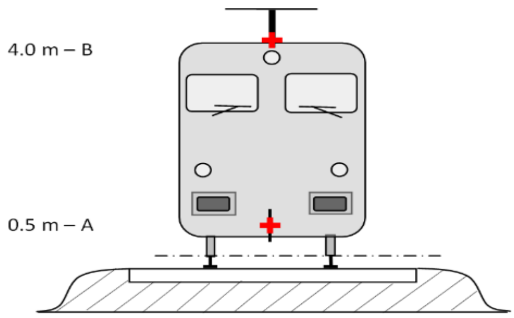

Fig. 1. Equivalent noise sources position

The roughness of wheels and railheads, through three transmission paths to the radiating surfaces (rails, wheels and superstructure), constitutes the rolling noise, which is allocated to h = 0.5 m.

The equivalent source heights for traction noise vary between 0.5 m (source A) and 4.0 m (source B) presented in Figure 1, depending on the physical position of the component concerned. Sources such as gear transmissions and electric motors will often be at an axle height of 0.5 m (source A). Louvres and cooling outlets can be at various heights; engine exhausts for diesel-powered vehicles are often at a roof height of 4.0 m (source B). Other traction sources such as fans or diesel engine blocks may be at a height of 0.5 m (source A) or 4.0 m (source B). If the exact source height is in between the model heights, the sound energy is distributed proportionately over the nearest adjacent source heights.

Aerodynamic noise effects are associated with the source at 0.5 m (representing the shrouds and the screens, source A), and the source at 4.0 m

(modelling all over roof apparatus and pantograph, source B). The choice of 4.0 m for pantograph effects is known to be a simple model, and has to be considered carefully if the objective is to choose an appropriate noise barrier height.
Impact noise, squeal noise and bridge noise are associated with the source at 0.5 m (source A) [2].

The impact of using the new CNOSSOS-EU method for assessing railway traffic noise is quite significant for Romania, because it is necessary to define the railway vehicles operating in Romania in terms of acoustic emission. This characterization must be carried out before starting the development of strategic noise maps for rail traffic using CNOSSOS-EU method. The CNOSSOS-EU railway model is based on the railway and wheel roughness [3], [10] and this roughness of the contact surfaces between the wheel and the rail are the cause of the rolling noise generated by the train in motion (Fig. 2).

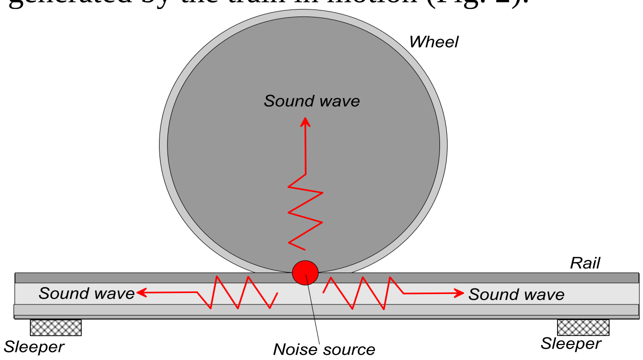

Fig. 2: Propagation of vibrations generated by contacting the wheel - the rail caused by roughness

According to CNOSSOS-EU method the rolling noise have two components: the vehicle contribution and the track contribution which are separated into four essential elements: wheel roughness, rail roughness, vehicle transfer function to the wheels and to the superstructure (vessels) and track transfer function.

For rolling noise, therefore, the contributions from the track and from the vehicle are fully described by these transfer functions and by the total effective roughness level.

The total effective roughness level is given by the following relationship:

$$L_{R,TOT,i} = 10 \cdot \lg\left(10^{L_{r,TR,i}/10} + 10^{L_{r,VEH,i}/10}\right) + A_{3,i} \tag{1}$$

Where:

$L_{r,TR,I}$ - the rail roughness *level* (track side roughness) for the *i*-th wave-number band;

$L_{r,VEH,i}$.- the wheel roughness *level* (vehicle side roughness) for the *i*-th wave-number band

A3(λ) - contact filter to take into account the filtering effect of the contact patch between the rail and the wheel, which depends on the rail and wheel type and the load.

Three speed-independent transfer functions, $L_{H,TR,i}$ $L_{H,VEH,i}$ and $L_{H,VEH,SUP,i}$, are defined: the first for each *j*-th track section and the second two for each *t*-th vehicle type. They relate the total effective roughness level with the sound power of the track, the wheels and the superstructure respectively (only for freight wagons) [2].

For sound power per vehicle the rolling noise is calculated at axle height, and has as an input the total effective roughness level $L_{R,TOT,i}$ as a function of the vehicle speed *v*, the track, vehicle and superstructure transfer functions $L_{H,TR,i}$, $L_{H,VEH,i}$ and $L_{H,VEH,SUP,i}$, and the total number of axles N_a:

for *h* = 1:

$$L_{W,0,TR,i} = L_{R,TOT,i} + L_{H,TR,i} + 10 \times \lg(N_a) \text{ dB} \tag{2}$$

$$L_{W,0,VEH,i} = L_{R,TOT,i} + L_{H,VEH,i} + 10 \times \lg(N_a) \text{ dB} \tag{3}$$

$$L_{W,0,VEHSUP,i} = L_{R,TOT,i} + L_{H,VEHSUP,i} + 10 \times \lg(N_a) \text{ dB} \tag{4}$$

Where N_a is the number of axles per vehicle for the *t*-th vehicle type [2].

The coefficients for $L_{r,TR,I,}$, $L_{r,VEH,i}$., A3(λ), and transfer functions $L_{H,TR,i}$, $L_{H,VEH,I}$, $L_{H,VEH,SUP,i}$, are mentioned in Appendix G “Database for railway source” from Directive 2015/996 [2]. This coefficients are mentioned taking into consideration break types, vehicle types, rail roughness (for well maintained and very smooth or for normally maintained smooth), axle load and wheel diameter and track base/rail pad type.

Taking into consideration the CNOSSOS-EU approach regarding rolling noise it is clear that is necessary to create a database with typical values of the surface roughness along the railway network in Romania by theoretical corrections of data regularly measured and also the acoustical measurements need to be made in order to have a train’s characterization, because the railways in Romania are not all well maintained smooth or normal maintained smooth.

But, the separate assessment of wheel and track contributions generally involves vibrato-acoustic measurements. In principle, the total rolling noise level and the vibration levels determined on the rail and the sleeper, are measured simultaneously.

By converting vibrations into noise levels, the contribution of the railway is determined.

In present, a modern method, named TWINS method, developed by UIC Committee C163 (Railway Noise), can be used to evaluate contribution differentiation by using Finite Element Method.

Without solve these issue regarding roughness noise measurements the noise maps for railway traffic in Romania cannot be done using CNOSSOS-EU methods or will be done with assumption that Romanian railways are well maintained smooth or normal maintained smooth.

For this reason the decisions regarding locations where action is required will have been made based on the noise levels in the noise map. But, some assumptions regarding noise source terms used for carrying out the noise mapping predictions will need to be reviewed to determine whether they are valid at the site under investigation.

So, in order to carrying out the noise mitigation actions applied to wheel or track, an expedient method, which is presented below, can be used when more accurate measurement methods are not available.

This expedient method it starts from the fact that a synthesis of several detailed studies carried out in this field [11] highlighted the relative positioning of the frequency spectra of the components of rolling noise according to Figure 3.

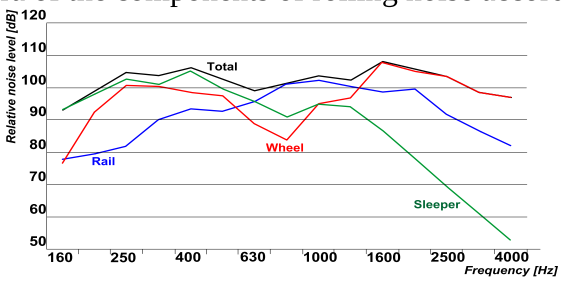

Fig. 3. The relative positioning of the frequency spectra of the components of rolling noise

As can be seen in Figure. 3, up to frequencies of 1600 Hz, the total noise level is significantly higher than the corresponding noise level of the wheel. It results that L_{track}, i.e. the level of noise corresponding to the rail and the sleeper is dominant within this frequency range. Also, over 1600 Hz, L_{track} is far below L_{total}.

Hence, in an approximate approach, total noise up to the 1600 Hz frequency can be considered as the noise generated by the track (rail and sleeper).

Only like an example, in Table 3, the noise level values in 1/3 octave frequency bands was generated from Figure 3 which is a general result from studies carried out of the number of years [9].

Table 3

Total noise level values in 1/3 octave frequency bands

F (Hz)	160	200	250	315	400	500	630
L(dB)	93.5	99	105	104	106	102.2	99
F (Hz)	800	1600	2000	2500	3150	4000	
L(dB)	102.5	108.5	106	104	98.7	97	

Applying the weight A (A-weighted), we obtain:

- the total noise level: L_{total} = 114.6 dB (A)
- the noise level corresponding to the track (up to 1600 Hz): L_{track} = 112.8 dB (A)
- the appropriate wheel noise level:

$$L_{wheel} = 10\lg\left(10^{\frac{L_{total}}{10}} - 10^{\frac{L_{track}}{10}}\right) = 109.9 \text{ dB(A)} \quad (5)$$

If $L_{track} - L_{wheel}$ > 10 dB(A), the track contribution dominates the total rolling noise.

If $L_{wheel} - L_{track}$ > 10 dB(A), wheel noise dominates the total rolling noise.

Because in our example the L_{track} - L_{wheel} = 112.8 dB(A) – 109.9 dB(A) = 2.9 dB(A), the situation is not clear domination of either L_{wheel} and L_{track}, and for this reason it may be necessary to mitigate both the wheel and track noise in order to reduce the total noise.

Using this expedient method it is possible to find which type of mitigation is needed, the rail treatments in isolation, the wheel treatments in isolation, or both.

2.3. Air traffic

In the case of air traffic in 2007-2018 in Romania the noise assessment was made using the interim method which is ECAC Doc. 29 "Report on Standard Method of Computing Noise Contours around Civil Airports", 1997 [12].

The CNOSSOS-EU method uses the third edition of ECAC Doc. 29 as well as the ANP (Airborne Noise and Performance Database) database [13].

From the point of view of the implementation of the CNOSSOS-EU method in Romania, there will be an impact on the increase of the accuracy of the strategic noise maps for air traffic because the radar data will be used as input data, processed in advance.

Also, the CNOSSOS-EU method specifies that need to taking into account the helicopter traffic where the airports have heliports, but the traffic of helicopters in Romania is low, leading to an insignificant impact on the noise mapping.

2.4. Industrial sources

In the case of industrial noise sources in 2007-2018 in Romania, noise assessment was carried out using the interim method which is ISO 9613-2: "Acoustics - Abatement of sound propagation outdoors, Part 2: General method of calculation [14].

The CNOSSOS-EU method for industrial sources has two potential minuses that in some cases can lead to lower accuracy of the results obtained.

These are the following:

- The CNOSSOS-EU method for industrial sources uses the octave bands between 64 Hz and 8000 Hz, and the octave band for 31.5 Hz is omitted. So, if the component for this octave band is significant in the total noise, then this 31.5 Hz band should considered;
- Corrections for attenuation of vegetation and ground attenuation used for industrial noise are absent in the CNOSSOS-EU method for assessing industrial noise.

Until these issues are solved at EU level by updating CNOSSOS-EU methods, when the strategic noise maps for industrial sites are made it is necessary to verify by means of acoustic measurements whether the octave band of 31.5 Hz has a significant contribution to total noise.

It is also necessary to present at the same time the noise assessment made using the interim method (SR ISO 9613-2: Acoustics - Attenuation of sound during propagation outdoors, Part Two: General calculation method), which has attenuation given by vegetation and ground, in order to make a comparison of the results obtained.

3. Contribution of authors

The author's contribution was focus to find a solution to the non-existence of the roughness noise measurements of the wheel and the rail in Romania in order to find which noise mitigation is needed.

Thus, as a novelty element brought about by this scientific paper, the authors proposed an expedient method, specified in chapter 2.2, with the help of which is possible to find which type of mitigation is needed for the noise caused by the wheel and track interaction (the rail treatments in isolation, the wheel treatments in isolation or both), which can be used especially when more accurate measurement methods are not available.

4. Conclusions

It is expected that the CNOSSOS-EU method will add extra accuracy to strategic noise maps, especially for traffic noise sources (road, rail and air), if it's provided the quality input data to use this method.

In the case of road traffic, the major impact of the implementation of the CNOSSOS-EU method in Romania is due to the need to develop traffic censuses and traffic studies that take into account the types of vehicles specific to this method (4 types of vehicles instead of 2 types used in the former method).

Especially for road traffic inside agglomerations will be a great challenge for local authorities to made traffic studies taking into consideration 4 types of vehicles, but, for a good noise maps accuracy it is very important that local authorities to have this traffic studies.

The effort to carry out these traffic studies prior to the elaboration of noise maps is the biggest challenge for the implementation of the CNOSSOS-EU method for road traffic in Romania.

In the case of railway traffic, the major impact of the implementation of the CNOSSOS-EU method in Romania is given by the capacity to carry out characterization of the noise sources for railway vehicles operating in Romania and also to generate typical values of the surface roughness along the Romanian railway network, by theoretical corrections of data regularly measured.

At present, there is no railway roughness data in Romania and the railway roughness measurements would require a lot of effort. The characterization of the noise sources for railway vehicles operating in Romania and to obtain the typical values of the surface roughness along the Romanian railway network, requires acoustic measurements to be made prior to the development of noise maps for the Romanian railway traffic.

For this reason, the National Railway Company from Romania before will make the strategic noise maps for railway traffic need to carry out characterization of the noise sources for railway vehicles and also to generate typical values of the surface roughness along the railway network structured in a database which need to be update periodically.

As in the case of SRM II method, also for CNOSSOS-EU method the contribution of aerodynamic noise is insignificant as trains in Romania are running at low speeds, generally below 100 Km/h.

In the case of air traffic the implementation of the CNOSSOS-EU method in Romania does not require special adaptations, but the major impact of this implementation is given by the use of radar data in the processing of input data used in noise mapping.

Until now, the strategic noise maps for air traffic was made using standard flight paths.

The use of radar data requires that they be processed so that they can be used as input data for noise map development, and this activity involves additional costs in making noise maps, but the accuracy of noise maps will be better because will presented the noise situation as a result of data provided by radar and not by using standard flight paths like in the past.

In the case of industrial noise sources, the implementation of the CNOSSOS-EU method in Romania does not require special adaptations, but it is possible to decrease the accuracy of strategic noise maps by using this method compared with the previous period when the interim method was used because the CNOSSOS-EU method does not show the corrections for attenuation for vegetation and ground.

So, in the case of road, rail and air traffic, if good quality input data are used, an increase in the accuracy of strategic noise maps is expected through the use of the CNOSSOS-EU method, for this reason it is very important to have traffic studies for road traffic and to use them in noise mapping, to use radar data in noise mapping for air traffic and to carry out characterization of the noise sources for railway vehicles operating in Romania and also to generate typical values of the surface roughness along the Romanian railway network, by theoretical corrections of data regularly measured, before noise maps are done for railway traffic.

Unfortunately, because the CNOSSOS-EU methods are mandatory to be used only started with 2019, there are no many analyzes of the impact of the implementation of these methods in other EU countries.

Only Finland made strategic noise maps with CNOSSOS-EU methods before 2019, but this country has not used in the past the Interim methods (Finland used Nordic Prediction Method - NMP96), so Finland's example is not a good one for Romania in order to have a comparison of the impact of implementation.

In Italy, a study was carried out in the city of Trento, an alpine agglomeration in North of Italy, and a comparison between Interim method and Cnossos-EU method, for road traffic, was made.

Thus, according to this study, in the case of traffic noise assessment using both the Interim method and the CNOSSOS-EU method, the conclusion was that a significant reduction of the number of people exposed to noise might derive from the application of the CNOSSOS-EU Road Guideline [15].

But in this study was not possible to classify the heavy vehicles with scientific criteria, and for this reason this study is not a good example for Romanian agglomerations situation, where inside the agglomerations exist an important percent of heavy vehicles in traffic.

In Germany, environmental federal authority had some activities in the implementation of CNOSSOS-EU, but this country has not used in the past the Interim methods for roads and rails noise mapping (Germany used the national methods) so German's example is not a good one for Romania in order to have a comparison of the impact of implementation.

R E F E R E N C E S

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