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ASSESSMENT OF NOISE ON THE FACADES OF RESIDENTIAL BUILDINGS AS A RESULT OF THE DEVELOPMENT OF A RAILWAY LINE WHICH SERVICING A CARGO TERMINAL OF THE GIURGIU PORT

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The paper introduces some aspects concerning the impact of noise on the residential buildings because of the reopening of an old railway section in their immediate proximity. As a novelty, in order to assess correctly the area and be able to use the SRM II computation method for estimating the noise at the facade level of residential buildings, we had chosen a similar situation to made measurements for characterization of the emissions coming from rolling noise and braking noise and we applied corrections of the rolling noise for a certain percentage of braking time which is specific to the analysed area.

Keywords: noise assessment, traction noise, rolling noise, braking noise, acoustic modelling, noise map, noise barrier

1. Introduction

At present, the assessment of the noise generated by the port activity is done with modern noise mapping tools by developing the 3D model of the analysed areas, considering specific features such as port positioning, residential neighbourhood positioning, ground access ways (roads, railways) that serve it [1], [2], [3].

The purpose of this study is to evaluate the acoustic phenomenon generated by the possible arrangement of a future railway line serving the cargo terminal of port Giurgiu, by analyzing the noise impact on the residential buildings because of the railway traffic on this railway line.

This evaluation was made by adaptation the Dutch national method SRM II to the specificity of the train types which will circulate on the studied railway section. The SRM II is developed for 10 categories of specific trains which are different from the trains that operate in Romania as such this method cannot be used in Romania without adaptation.

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This paper assesses the acoustic implications of the future construction of a railway section that will serve the cargo terminal of Giurgiu port.
The existence of residential buildings near the railway requires an assessment of the noise impact produced and the solutions to diminish it.
The usefulness of the project is the increase of goods flow in the cargo terminal area of Giurgiu port, this terminal having the function of transfer of goods in both directions between the railway transport and the river transport on the Danube River (Fig. 1).

Fig. 1: Location of the area in which the project is to be carried out

2. Description of the Analysed Situation

The conjunction between the container terminal and the main railway network will be ensured by the arrangement of a simple railway line of about 900 m in length.
The freight trains to be operated on this line will consist of up to nine wagons plus the locomotive, a constraint imposed by the container terminal size.
For safety reasons, transit will be at low speeds of up to 10 km/h in a mode where the braking movement will be on about 25% of the total length of the track line, the braking movement alternating with the movement without braking this being specific to situations in which freight wagons are operated at low speeds.
In Romania there is no calculation method for railway traffic noise. So, SRM II [4] had to be adapted to the situation of Romanian trains. The analysed situation represents a future situation for which no acoustic measurements could be made, so, I made acoustic measurements on a similar situation resulting in a brake emission of about 7 dB (A) greater than the rolling emission. Since, for the area specified in the study, the braking time, when we have 7 dB higher emission in the braking conditions, is about 25% from the running time (T period), it results that for this railway segment in the T period, the resulting emission (due to rolling noise and braking noise) will be with about 3 dB bigger that emission during rolling noise

before braking condition (or with about 4 dB smaller that emission during braking noise), as shown by the following relationship.

$$E = 10 * \lg\left[\left(\frac{1}{T}\right) * \left(0.75 * T * 10^{\frac{E_r}{10}} + 0,25 * T * 10^{\frac{E_r+7}{10}}\right)\right] = E_r + 3\,\text{dB} \qquad (1)$$

where: E is resulting emission and E_r is emission due rolling noise before the braking condition.

As a matter of fact, in can be noticed that at low speeds of train with brake blocks, the noise emission during braking is variable depending on the way in which the train operator is driving the brake.

The use of LDH 1250 hydraulic diesel locomotives is envisaged and freight wagons will be differentiated according to the type of goods to be transported.

Fig. (2) schematically illustrates the variation of the sound pressure level according to the speed of the trains for each type of noise source and in Fig. (3) are plotted the heights of the noise sources according to the type of noise source.

Thus, it can be seen from Fig. (2) that the traction noise is the predominant component of the total noise at traffic speeds of up to about 30 km/h and at traffic speeds above 30 km/h the rolling noise is predominant.

Fig. (4) shows the justification for choosing a height of 4 meters for traction noise.

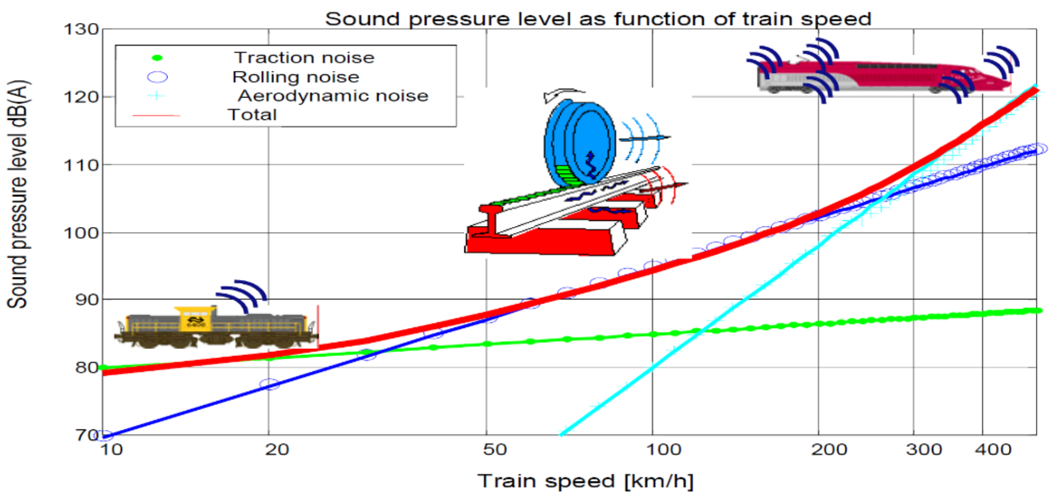

Fig. 2: Relative description of the noise sources associated with the speed of a train, described in [5] page 7 and [6] page 13

In accordance with the provisions of the Directive no. 2002/49/EC, transposed into national law by [7], Romania uses the SRM II - 96 Dutch method as an interim computation method.

Documents [6] and [8] present the main changes made in order to adapt the Dutch method described in document [4] taking into consideration the trains characteristics in Romania, however, not all these changes are useful for this study. From document [6], only the calculation mode for correction on length of train can be used for this study. The second adaptation regarding the correction for rolling noise which is mentioned in these documents is not useful, since it was made for trains which generally circulate with speeds bigger of 50 km/h for the strategic noise mapping purpose according [5], however. At these speeds, the dominant component in the total noise of trains is the rolling noise. As such, in this study, as a novelty, we have applied an adaptation in order to use SRM II for the trains which circulate with maximum 10 km/h, since in this situation in the total noise of trains the traction noise is the dominant component and not the component of the rolling noise. Thus, the correction applied to the rolling noise is lower in this case.

Another novelty, for the area specified in the study it is necessary to make a characterization of emissions coming from rolling noise and braking noise for a certain percentage of braking time, since for this particular railway section the braking time is about 25% from the running time (T period).

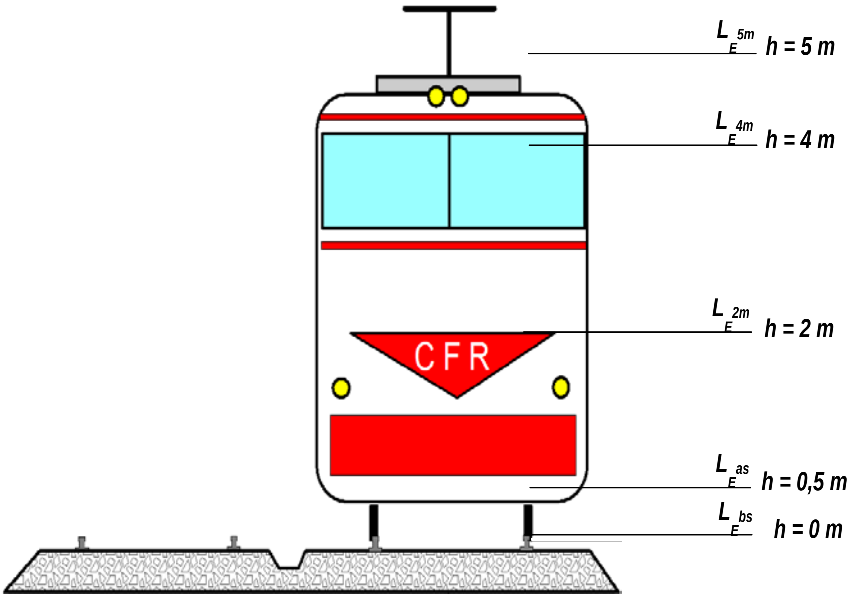

Fig. 3: Noise sources and their height (h - source height, L_E – level of emission) described in [9] page 144

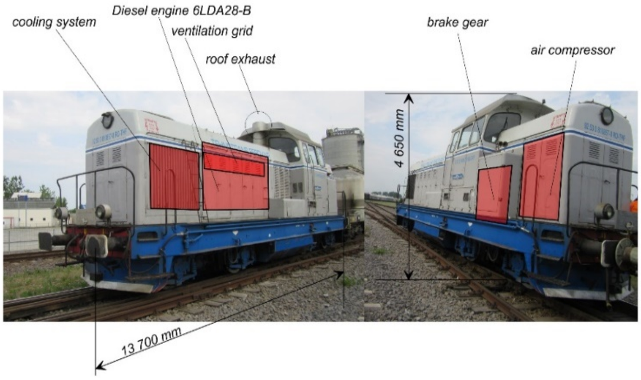

Fig. 4: Noise sources associated with the operation of the LDH 1250 locomotive at standstill with the engine running. The justification for choosing the average 4 m height for traction noise emission: the traction noise components are located at different heights (exhaust, air compressor, ventilation grid, Diesel engine) and for this reason the calculation methods use an average height for the traction noise source.

3. Modus Operandi

According to SRM II - 96, freight trains are classified in the 4th category of their classification in the Dutch legislation and the equivalent noise level in dB(A) is computed as follows [4]:

$$L_{Aeq} = 10 * \lg \sum_{i=1}^{8} \sum_{j=1}^{J} \sum_{n=1}^{N} 10^{\frac{\Delta L_{eq,i,j,n}}{10}} \tag{2}$$

where $\Delta L_{eq,i,j,n}$ specifies the contribution in an octave band (index code i) of sector (index code j) and a source point (index code n) and includes following values, specified and detailed in [4] and in [9]:

$$\Delta L_{eq,i,j,n} = L_E + \Delta L_{GU} - \Delta L_{OD} - \Delta L_{SW} - \Delta L_R - 58.6 \tag{3}$$

where:

L_E emission value per source type and octave band,

ΔL_{GU} attenuation due to distance,

ΔL_{OD} attenuation due to propagation,

ΔL_{SW} screening effect, if present,

ΔL_R attenuation due to reflections, if present.

These equations are described in detail in [4] and in [9], and for the computation the corrections for the length of trains being operated in Romania according to [6], pages 15-17, were applied. Additionally, as a novelty, from the noise measurements found in similar situation, a correction has been applied for rolling noise of this

particular type of trains that will run on this railway section and also we made a characterization of emissions coming from rolling noise and braking noise for a certain percentage of braking time, because for this particular railway section the braking time is about 25% from the running time (T period) .
The 3D digital model of the area containing the noise emission-specific elements as shown in Table 1, as well as the existing obstacles which are influencing the propagation of the noise, has been accomplished.
The advantage of creating a 3D digital model is the possibility of simulating by computation the situations that are of interest as well as to calculate the size of the noise barriers to dimensions that provide acceptable protection for neighbouring residential buildings.
The computation took in consideration, as cover up, an average traffic of 1 train/hour.

Table 1

Input data on the noise emission sources used in the noise assessment

	F[Hz]	63	125	250	500	1000	2000	4000	8000	$=10*\lg\left(\sum_{i=1}^{n}10^{\frac{L_i}{10}}\right)$
Rolling noise										
1	a [1]	30	74	91	72	49	36	52	52	
2	b [1]	15	0	0	12	25	31	20	13	
3	L_{ER} for v = 8 km/h	43,55	74	91	82.83	71,6	64	70	63	91.8
4	$L_{ER\ corrected}$ according [6]	54,55	85	102	93.83	82.6	75	81	74	102.8
5	L_{ER} at h = 0 m	51,55	82	99	90.83	79,6	72	78	71	99.8
6	L_{ER} at h= 0.5 m	51,55	82	99	90.83	79.6	72	78	71	99.8
Rolling noise + Braking noise (logarithmic summation)										
7	$L_{E\ during\ braking}$ (similar situation)	59,5	91	108,5	102	98	91	90	82	109.8
8	$L_{E\ total}$ (with 25% braking and 75% without braking)	56,4	87,4	104,7	97,6	92,3	85,3	85,4	77,7	105.8
Rolling noise + Braking noise at h = 0.5 m										
9	L_E at h =0.5 m	54,7	85,9	103,4	96,6	92,1	85,1	84,5	76,6	104.6
Traction noise										
10	L_E at h = 4 m	74,18	80,68	85,74	92,4	95,4	96,2	94,3	88,7	101.2

where:
E - Emission index
a, b - coefficients for determining the rolling acoustic emission, depending on the train speed (pages 52 - 55 and Table 18 of [9]).

The row 3 contains the result of applying the following relationship for v = 8 km/h and for Q = 1 train/hour [8]:

$$E = a + b * \lg(v) + 10 * \lg(Q) \quad (4)$$

The row 4 contains the result of about 11 dB corrections applied, as follows:

- correction of 3 dB according [6], for the fact that the train length of 10 wagons which is analysed is double that the train of 5 wagons (category 4 from SRM II);
- correction of 8 dB, as a novelty, made from noise measurements in similar circumstances for characterization of the emissions coming from rolling noise.

By logarithmic summation for all frequencies, the total emission level for rolling noise corrected is obtained:

$$L_{ER} = 10 * \log(\sum 10^{\frac{L_i}{10}}) = 102.8\,\text{dB(A)} \quad (5)$$

Also, using the same type of relationship, we obtain the fallowing results for:

- L_{ER} = 91.8 dB(A) for v = 8 km/h (without about 11 dB correction);
- L_{ER} = 99.8 dB(A) for h = 0 m and h = 0.5 m (rolling noise levels are decreased by 3 dB by equal distribution);
- $L_{E\ during\ braking}$ (similar situation) = 109.8 dB(A) which is bigger with about 7 dB that L_{ER} corrected = 102.8 dB(A);
- $L_{E\ total}$ = 105.8 dB(A), the total emission levels for rolling and braking for the area specified in the study (with 25% braking and 75% without braking) which is smaller about 4 dB that $L_{E\ during\ braking}$ = 109.8 dB (A) or which is bigger about 3 dB that $L_{ER\ corrected}$ = 102.8 dB(A).

The rows 5 and 6 represent the results of rolling noise distribution between h = 0 m and h = 0.5 m (rolling noise levels are decreased by 3 dB by equal distribution).

The row 7 contain the noise levels during braking condition, measured for a similar situation.

The row 8 contain the total emission levels for rolling and braking for the area specified in the study (with 25% braking and 75% without braking) which is obtain by logarithmic summation of $L_{ER\ corrected}$ with $L_{E\ during\ braking}$.

The row 9 contain the noise level for rolling and braking condition for h = 0.5 m, the value which are obtained by decreasing (logarithmic) the rolling emission values for h = 0 m (row 5) from the total emission levels for rolling and braking for the area specified in the study (row 8).

The row 10 contain the noise level for traction noise for h = 4 m.

Note: According to [9], page 53, for category 4, in which freight trains are assigned, the rolling emission for the non-braked condition is distributed between the emission lines located at 0 m and 0.5 m. Emissions from braking were distributed at 0.5 m height. Emissions from traction noise were distributed at 4 m height, as indicated in [9], chapter 2.2.10.1, page 42.

The noise indicator taken in consideration in the noise assessment at the facade of residential buildings is L_{eq} as the assessment is made for a calendar day in which the estimated number of trains is one per hour, respectively 24 trains per day and the results are compared with the limit values from [10].
Obviously, an assessment can also be made using the L_{den} and L_{night} indicators according to [7] but in this case, the assessment should be made for a calendar year and for an average annual number of 24 trains/day x 365 days/year = 8760 trains/year and the results would then be compared with the limit values from [11]. However, the aims of these two approaches are different.
In the case of an assessment based on the L_{eq} indicator, the purpose is to analyse the conditions under which a future railway next to a residential building can be operated with respect to the limit value associated with this situation of 50 dB (A) provided in [10].
In the case of an assessment based on L_{den} and L_{night} indicators according to [2], the purpose is to analyse an existing situation (which is not the case here), so that the competent authorities, after making a noise map, assess what measures could be taken to ensure that the limit values set out in [11] are met.
The way of working to assess the impact of noise generated by railway activity on residential buildings involved several stages of work.
In a first step, based on the image in Fig. 1, a 3D digital model was plotted (Fig. 5).

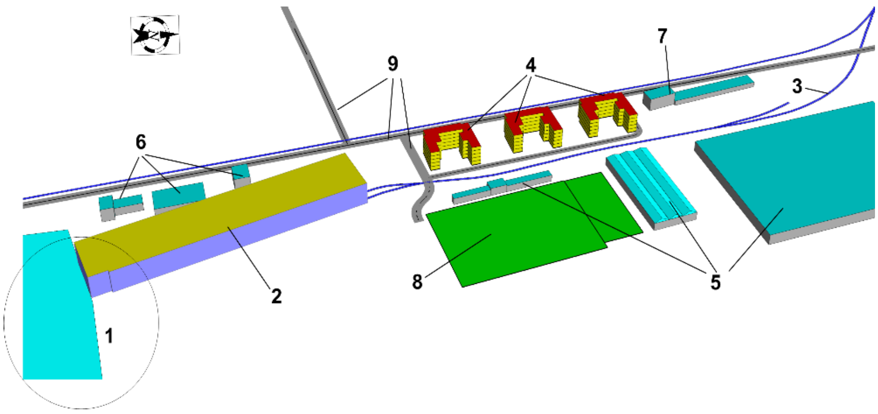

Fig. 5: The 3D digital model of the area under analysis

1 –Giurgiu port
2 – Cargo terminal
3 – Railroad
4 – Residential buildings
5 – Industrial buildings
6 – Office
7 – Railway station
8 – Stadium
9 – Roads

Subsequently, after the plotting of the 3D digital model, it was used together with the data in Table 1 in a trial version of the SoundPlan mapping software and the SRM II method described in [4] and [9] was used for computation.

By simulation, the following were obtained:

- the distribution of noise levels at 1.5 m height at the facades of residential buildings, without noise barriers (Fig. 6);
- the distribution of noise levels at 13.5 m height at the facades of residential buildings, without noise barriers (Fig. 7);
- the distribution of noise levels at 1.5 m height at the facades of residential buildings, with noise barriers of 2.5 m in height (Fig. 8);
- the distribution of noise levels at 13.5 m height at the facades of residential buildings, with noise barriers of 2.5 m in height (Fig. 9);
- the distribution of noise levels at 1.5 m height at the facades of residential buildings, with noise barriers of 5.5 m in height (Fig. 10);
- the distribution of noise levels at 13.5 m height at the facades of residential buildings, with noise barriers of 5.5 m in height (Fig. 11).

Table 2

Noise levels under specified conditions

	The assessed situation	**The height for the distribution of noise levels at the facades of residential buildings [m]**	**Leq [dB(A)] ***
1	without noise barriers	1.5	54.0
2	without noise barriers	13.5	53.0
3	with noise barriers of 2.5 m in height	1.5	49.0
4	with noise barriers of 2.5 m in height	13.5	51.5
5	with noise barriers of 5.5 m in height	1.5	37.0
6	with noise barriers of 5.5 m in height m	13.5	< 50.0

(*) - by applying a 3 dB(A) correction because of eliminating reflection contribution.

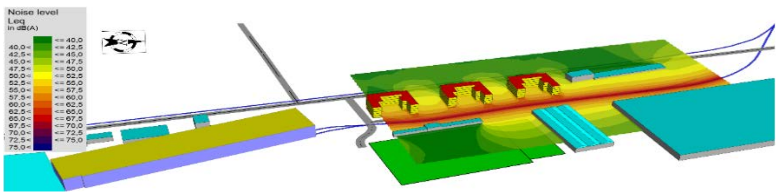

Fig. 6: Distribution of noise levels at 1.5 m height at the facades of residential buildings, without noise barriers

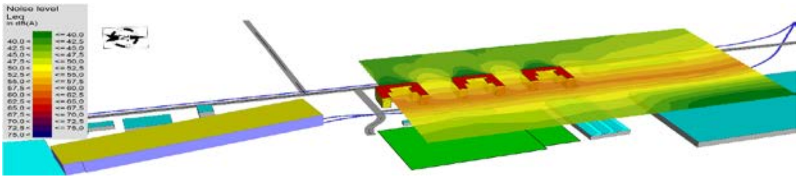

Fig. 7: Distribution of noise levels at 13.5 m height at the facades of residential buildings, without noise barriers

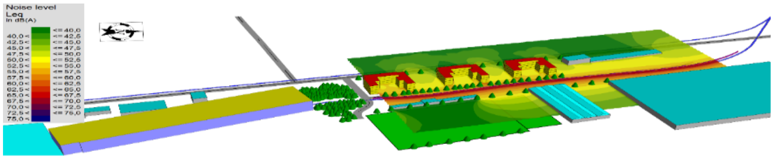

Fig. 8: Distribution of noise levels at 1.5 m height and provided the fitting of a noise barrier of h = 2.5 m near the railway line

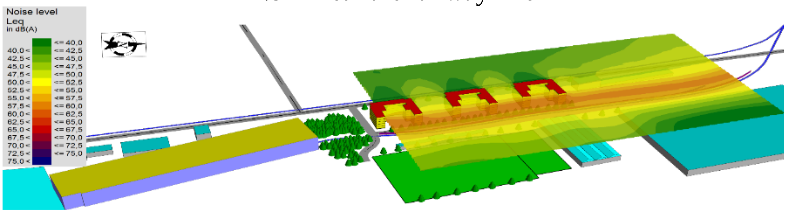

Fig. 9: Distribution of noise levels at 13.5 m height and provided the fitting of a noise barrier of h = 2.5 m near the railway line

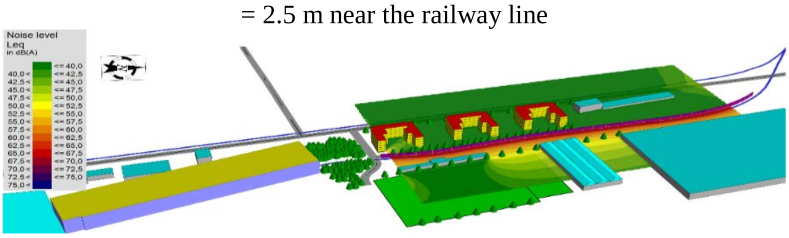

Fig. 10: Distribution of noise levels at 1.5 m height and provided the fitting of a noise barrier of h = 5.5 m near the railway line

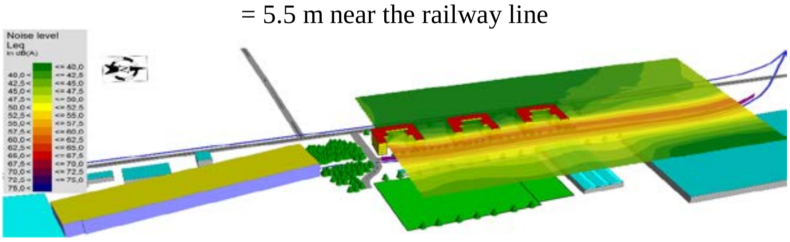

Fig. 11: Distribution of noise levels at 13.5 m height and provided the fitting of a noise barrier of h = 5.5 m near the railway line

The 1.5 m height for the distribution of noise levels was considered because, generally, acoustic measurements on the facades of buildings are made at this height. So, that for a possible comparison of the acoustic modelling with data to be measured after putting into use of the railway, the situation was represented also for this height

The 13.5 m height for distribution of noise levels was considered for including in this evaluation the last floor of the residential buildings at their external facade, both when a noise barrier is fitted and when there isn't.
Thus, from the initial assessment, in cases where there is no noise barrier fitted, we can notice that the limit of 50 dB(A) is exceeded, both at 1.5 m and 13.5 m height, as in the case of the situations presented in Fig. (6) and Fig. (7) and in table 2. Thus, it is clear, that the entire facade of each buildings near the railway line is exposed to values greater than the limit value of 50 dB(A) provided in [10].
Because the limit value is exceeded, the solution is to solve this problem using noise barriers.
The best descriptor of a barrier performance is the insertion loss that is the difference between the environmental noise prior and after a barrier has been installed. The height of a barrier and the proximity of a source and receptor are of main significance in the insertion loss offered by a barrier. Utilization of absorbing material is particularly important in this type of application. [12].
Thus, after clarifying the situation without noise barriers, in the 3D digital model the noise barriers were introduced in two versions: with 2.5 m height and 5.5 m height respectively (Fig. 12) and then the noise mapping was done again for each of these two new situations (Fig. 8 – Fig. 11 and table 2).

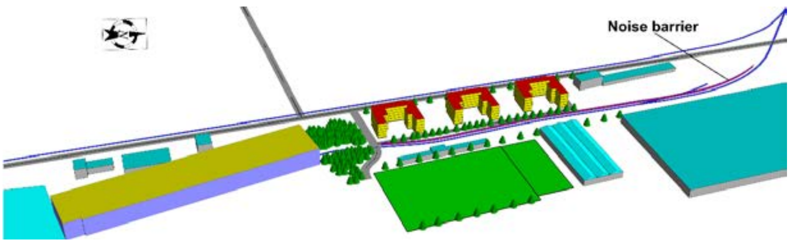

Fig.12: Including in the 3D digital model a noise barrier with a height of 2.5 m in the first version and a height of 5.5 m in the second version. For landscaping reasons, we also have foreseen planting some trees. Note: The noise protection function of trees is negligible.

As a result of the noise mapping made for 1.5 m and 13.5 m heights at the facades of the residential buildings, by taking into consideration a 2.5 m height noise barrier, it is noticed that the decrease in noise levels are unsatisfactory in the case of a height of 13.5 m and satisfactory for situation in the case of a height of 1.5 m presented in Fig. (8), Fig. (9) and also in table 2.
The main reason for this situation is that the 2.5 m noise barrier does not provide protection against the traction noise from trains running in the vicinity of the residential buildings, this noise source being positioned at a 4 m height as it is represented in Fig. (3) and Fig. (4) and featured in Table 1, i.e. at a height greater than the height of the panel.

Thus, it is noticed that the reduction in the noise levels due to the fitting of a 2.5 m height noise barrier will only provide partial protection against noise, i.e. it will provide a noise shield from the rolling noise and braking noise of the trains, which are the sources of the noise positioned at a lower height than the height of the noise barrier, respectively at 0 m and 0.5 m heights as shown in Fig. (3) and featured in Table 1.

Due to the noise mapping carried out for 1.5 m and 13.5 m heights at the facades of the residential buildings, by taking into consideration a 5.5 m height noise barrier, it is noticed that the decrease in the noise levels are satisfactory for both situations presented in Fig. (10), Fig. (11) and in table 2.

Due to noise barrier of 5.5 m, the noise levels obtained at facades, for both situations at the heights of 1,5 m and 13.5 m, are lower than 50 dB(A), the limit value imposed in [10].

Thus, the use of a noise barrier with a height of h = 5.5 m, will lead to the shielding of traction noise from the locomotives of the trains that will circulate near the residential buildings.

Also, one thing that should not be neglected is that after the arrangement of the railway subject to this study and after its commissioning, it is possible to carry out a follow-up check of the calculations made before the railway line construction, using noise measurements within a time range of 24 hours at the facades of the three residential buildings, at both 1.5 m and 13.5 m heights, so it is possible to verify the quality of the estimation achieved by noise mapping.

4. Conclusions

The study shows the usefulness of an appropriate noise mapping, in the case of railway trafic such as the one presented, with the judicious use of sound protection means, having as novelty, the application of a correction for rolling noise in the particular situation of the train type which will run on the studied railway section and the characterization of emissions coming from rolling and braking noise for a certain percentage of braking time, because for this particular railway section the braking time is about 25% from the running time.

Thus, from the noise mapping of the studied area, the following conclusions can be drawn:

- it is important to make the proper corrections for rolling noise from noise measurements in similar circumstances, and to apply corrections for this particular type of train which will circulate on this railway section;
- it is important to make the characterization of emissions coming from rolling and braking noise for a certain percentage of braking time, since for this particular railway section the braking time is about 25% from the running time;

- it is important that the studied area is 3D modelled as close as possible to the on-site reality, so starting from a real image of the area (Fig. 1) to obtain a 3D model of the area with the highest accuracy (Fig. 5);
- it is important that in the 3D model the noise barrier is correctly positioned and dimensioned (Fig. 12) to properly assess its effectiveness;
- it is important to properly analyse the noise source because the noise that is being analysed at the facade of the buildings is an total noise emitted by the railway traffic and during the movement of the trains, as shown in Fig. 3 and in Table 1, the noise produced has several emission sources, such as the rolling noise, the braking noise and the traction noise, each with different height, which must be taken into account when proposing any noise protection measures;
- if we have low train speeds, the traction noise source will always be predominant and the noise protection measures should take this into consideration, otherwise the noise barrier may be wrongly dimensioned (e.g., of 2.5 m height), which will be insufficient to protect residential buildings.

Noise assessment using noise mapping and computation methods (such as the SRM II - 96 method) to describe a future situation (as in the case of the railway line in this study, to be arranged for serving the cargo terminal of port Giurgiu) represent a solution that has the following advantages:

- allows the assessment of a non-existent situation for the time being, which can not be assess by noise measurement because the railway objective exists only in the project state;
- allows viewing of the future noise state by assigning a colour code to the value ranges of noise, which is very important for both, the cargo terminal administrator and the associated railway line operator, as well as for the citizens living in the residential buildings located in the analysed area, who will have access to this information before the project is implemented.

Also, a possible application of the results of this study is the possibility that in the environmental impact assessment studies for different investments in railway sector, similar approaches to noise assessment by noise mapping are used.

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[10] SR 10009:2017, Acoustics. Permissible limits of environmental noise level

[11] Order no. 152/558/1119/532-2008 for the approval of the Guidelines on the adoption of limit values and their application when drawing up the action plans for the L_{zsn} and L_{night} indicators in the case of noise generated by road traffic on main roads and in agglomerations, rail traffic on main railways and in agglomerations, air traffic at major and/or urban airports and noise generated in the agglomeration areas where industrial activities as set out in annex no. 1 to the Government Ordinance no. 152/2005 on Integrated Pollution Prevention and Control, approved with amendments and completions by the Law no. 84/2006.

[12] *Alina Mihaela Rădoi, Nicolae Enescu, Ioan Magheţi,* Determination of the Noise Barriers Performance for Protected Areas, Volume XIII, Issue 1, pag 31-34, The Romanian Journal of Acoustics and Vibration (ISSN 1584-7284) 2016