Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XII, 2023
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

EVALUATION OF THE INFLUENCE OF GREEN SPACE IN THE PROCESS OF REDUCING URBAN NOISE, ON THE TRANSVERSAL PROFILES OF TRAFFIC ROADS

Marta Cristina ZAHARIA, Gabriela VOLOACA

INCD URBAN-INCERC, 266 Pantelimon Street, District 2, Bucharest, Romania

Corresponding author email: marta_cristina_zaharia@yahoo.co.uk

Abstract

A special importance in designing the urban assemblies in cities, especially the configuration of the transversal profiles of the traffic roads, from the point of view of the acoustic and vibration protection for people, has the judicious design of the green spaces that are placed between the traffic roads and building front facades construction elements. Green spaces bring with a good contribution in the process of reducing urban noise, because of acoustic absorption characteristics they have. The relationship between the profile / size of urban road arteries in correlation with the size of adjacent green spaces and/or the distance from the running area to buildings can be evaluated from several points of view, including the effect of an earthquake. There were made research, in projects PN 23 35 01 01 and PN 23 35 06 01, by calculation studies regarding the values of the equivalent noise level, Lext (f), from traffic, - which were performed for a street-study profile, considered as a standard, then for other cases of study-road profiles. It was shown that for a traffic street of technical class 1 (with 8 lanes of traffic), bordered by two fronts of buildings of at least 8 floors high, having a complex composition of traffic, the two cases: without and with green area made by trees, shrubs and grass, indicates that values of transmission noise may decrease between 1 to 5 dB, depending on the winter and summer seasons.

Key words: *absorption coefficients, acoustics, civil buildings, green spaces/areas, urban noise.*

INTRODUCTION

The *design of the urban assemblies in cities* from the point of view of the *acoustic and vibration protection for people*, must be made in order to obtain an *urban noise level* that has values that fall within the provisions specified in the *technical regulations* (norme C125:2013) in force, regarding *building acoustics and urban acoustics*.

In designing *the configuration* of the *transversal profiles of the traffic roads bordered with buildings*, a special importance has the judicious design of *the green spaces* that are *placed between* the *traffic roads* and *building front facades construction elements*. (Zaharia M.C., 1999).

Also, green areas placed on the configuration of the traffic roads gives a beautiful aesthetic view and can improve the acoustic comfort of indoor spaces (Scamoni et al., 2022) and the urban spaces (Timothy Van Renterghem et al., 2009; Hyung Suk Jang et al., 2015, Zaharia M.C., 2020). An example of a street in the center of Bucharest is shown in Figure 1.

Figure 1. Image from street in center of Bucharest (internet image)

Green spaces bring with a good contribution in the process of *reducing urban noise*, because it constitutes an *acoustic barrier* and they have *acoustic absorption characteristics*.

On the other side, *the relationship* between *the profile / size of urban road arteries* in correlation with *the size* of *adjacent green spaces* and/or *the distance* from the running area to buildings *can be evaluated* from *several points of view*, including the effect of the transmision of *vibration waves* from an *earthquake* or from *traffic road service*.

Finaly the scope is *to obtain a decrease of traffic noise propagation, by reducing the reflection of acoustic and vibration waves:*
1) *between the fronts of buildings*
and
2) *between the noise source coming from traffic, to the receiver (people) located in the building* or *in the external environment*, in *a point A of the transverse profile of the traffic artery,*
according to *green spaces acoustic absorption characteristics*, respectively *the sound absorption coefficient*.
Considering the configuration of *green areas* like *big trees, with big roots in the ground*, can have also the effect of *a barrier* in transmision of *vibration waves* from an *earthquake* or from *traffic road service* to the *bordered building* of traffic roads.
The identification of the *destructive potential of seismic events* produced *in Romania* can be *preventively and effectively correlated* with *different parameters of the urban system* such as the *relationship between the profile / size of urban road arteries* in correlation with the size of *adjacent green spaces* and/or *the distance from the running area to buildings.*
The experience of the Vrancea earthquake of March 4, 1977 (Bălan et al., 1982) highlighted the following:
- the reinforced concrete structure or the masonry mortar of buildings from older generations, located on relatively narrow streets, *may suffer degradation over time* as a *result of repeated or aggressive mechanical stresses over decades, traffic in the immediate vicinity of the buildings* may be a cause aggravating;
- such phenomena are broadly comparable to those *of fatigue at a very large number of cycles*, which can *accumulate in several decades*, in *combination with the effects of strong earthquakes* (e.g. *traffic vibrations plus the earthquakes* of 1940, 1977, 1986 and 1990) and can lead to a *decrease in the strength of some concretes from older generations*;
- *modern isolation systems*, - including *green areas* -, against *vibrations from tram or subway tracks can reduce these negative effects*.

MATERIALS AND METHODS

According to Romanian technical regulation norm no. *C125:2013 Normative regarding Acoustics in constructions and urban areas, Part IV - Protection measures against noise in urban areas* (*subchapter 2.3.2.3.(2)*)*,* where there is a method of calculation the street exterior noise level, *Lext(f),* in one point from a transverse profile of a traffic artery, respectively *Level of noise in measurement point "A",* originated from several types of vehicles moving on multiple lane of a traffic road is in formula 1:

$$L_{ext}(f) = 10\lg\left(\frac{1}{T}\sum_{I=1}^{n} t_I \cdot 10^{\frac{L_I^A}{10}}\right) \text{ (dB)} \qquad (1)$$

,

in which:
L_I^A- the noise level corresponding to the action "I", (dB).
T - characteristic time period (in seconds (s)); (choose for example: 3600 s);
t_I - the duration of time corresponding to action "I" at the considered point;
$t_I = n_I \cdot \tau_I$, (s)
where:
n_I - the number of means of traffic of a certain type "I" which circulates in the characteristic period "T", for which the equivalent noise level is established;
τ_I - the time (in seconds), in which the vehicle covers a distance L = 20 metra.
The *level of noise in measurement point "A"*, *"L_I^A"*, originated from *a noise source type "I"*, in case of a transversal profile of traffic road which is *bourded with two fronts of buildings* and have ***green zones*,** is calculated (cf. Normative C125:2013, *Part IV, subchapter 2.3.2.3.(6)*) with the following geometrical elements from Figure 2 for determining the noise level, and the complex formula 2.

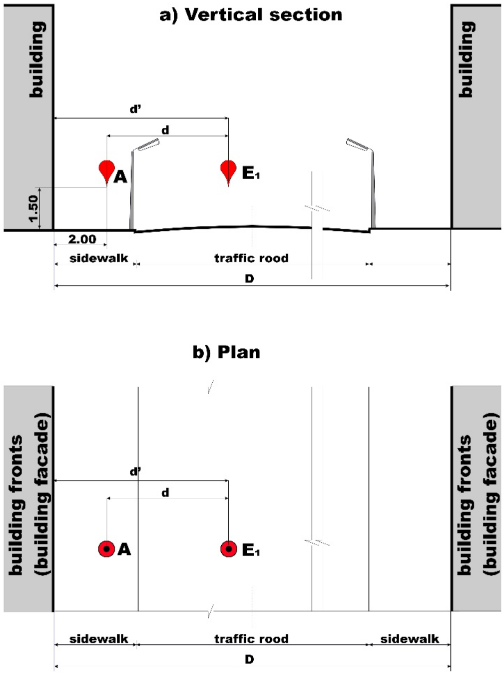

Figure 2. The geometrical elements for determining the noise level,
in case of a transversal profile of traffic road which is *bourded with two fronts of buildings*
A - measurement point (situated usually at 2.00 m distance from the building facade and at 1.50 m high distance from the ground); d - distance from noise source to the measurement point, (m); d' - distance from noise source to the building facade, beside it is made the measurement, (m);
D - distance between the buildings fronts (m); E1 - noise source

$$L_I^A = L_I^1 + 10\lg\left\{ \frac{1}{\left[\left(\frac{d}{d_0}\right)^{\frac{k}{10}}\right] c_s c_{zv}} + \frac{1}{\left(\frac{d'-d}{d_0}\right)^{\frac{k'}{10}}} \left[\frac{1-\alpha_1}{\left(\frac{d'}{d_0}\right)^{\frac{k}{10}}} + \frac{\frac{(1-\alpha_1)(1-\alpha_2)}{c_s c_{zv}}}{\left(\frac{D-d'}{d_0}\right)^{\frac{k}{10}} \left(\frac{D}{d_0}\right)^{\frac{k'}{10}}} \right] \frac{\left(\frac{D}{d_0}\right)^{\frac{k'}{5}}}{\left[\left(\frac{D}{d_0}\right)^{\frac{k'}{5}} - (1-\alpha_1)(1-\alpha_2)\right] c_s c_{zv}} \right\} \text{(dB)..(2)}$$

in which:

k - directivity coefficient of the source; corresponds to the propagation of direct waves from the source to the measurement point; the direction of the waves is considered perpendicular to the front of the buildings.

k = 20, for a spherical source (example: a car);

k = 10, for a cylindrical linear source (example: usual road traffic);

k = 0, for parallel linear sources (example: road traffic continuous flow, unrealistic situation).

k' - directivity coefficient of reflected waves between building fronts.

k' = 10, on the traffic arteries bordered by a single front of buildings;

k' = 5, in the case of traffic arteries bordered by two fronts with at most 4 floors;

k' = 3, in the case of traffic arteries bordered by two fronts of buildings with max. 4 floors on one side and 4 ... 8 floors on the other side;

k' = 0, in the case of traffic arteries bordered by two fronts of buildings with at least 8 floors.

α_1 - the acoustic absorption coefficient of the facades of the buildings located on the side of the traffic artery on which the measurement point is located.

α_2 - the acoustic absorption coefficient of the building facades located on the side of the traffic artery opposite the measurement point.

The acoustic absorption coefficient, **"α_i"**, depends on the architectural configuration of the facades, represented by the coefficient **"φ"**:

φ = 1 - for flat facades;

φ = 1.1 - for facades provided with continuous balconies;

φ = 1.2 - for facades provided with continuous loggias.

The acoustic absorption coefficient, "α_i", corresponds to the area **"S_i"** made of material "i" on the facade.

The **"S_A^I"** area in the front of the buildings, related to the measurement point "A", made up of "n" acoustically different areas, "S_i".

"L_i^1" - the noise levels characteristic of the considered mobile sources, which are rounded, for calculation, into five noise classes: 70, 75, 80, 85, 90 dB(A); each class includes vehicles whose characteristic noise level deviates by no more than ±2 dB (A) from the class definition value.

n_1 - the number of vehicles with a noise level less than or equal to 80 dB that pass on the traffic artery, in a 1-hour time period;

n_2 - the number of vehicles with a noise level higher than 80 dB that pass on the traffic artery during the same period;

The number of means of traffic of a certain type "n_i" that circulates in the characteristic period "**T**", "**n_i/h**", is determined by measurements or established by statistical calculations, depending on: the type of means of transport, the number of vehicles per hour "n_i/h", in both directions, depending on *the technical class of the street*, the considered time period (hour).

τ_i - the time (sec), in which the vehicle covers a distance L = 20 m, specific for different types of means of traffic circulating at characteristic speeds.

"**c_s**" - coefficient depending on the nature of the road surface or the land surface; example: c_s = 0.85 for Cubic stone; c_s = 0.90 for Asphalt; c_s = 1.00 for Earth; c_s = 1.10 for Turf; c_s = 1.20 for Sand.

"**c_{zv}**" - coefficient depending on ***the type of green area***.

The green spaces in urban and / or rural areas ***can be made*** usually *with **different types of green plants***, such as the following:

A) the ***type of green area***: a) conifer plantations, b) deciduous plantations, c) the area with grass or earth, etc.,

B) the ***number of rows*** on which ***trees with interlaced crowns*** are planted, and if they have ***little trees*** and ***shrubs*** planted *between the stems*,

C) the ***number of rows*** on which the ***trees with uncrossed crowns*** are planted,

D) the ***area without trees***,

E) the ***season: summer*** or ***winter***.

The values of the "c_{zv}" coefficient depending on the type of green area are presented in table 1 (cf. Norm no. C125:2013, *Part IV*).

In Table 1 it is considered only the situation, most frequently found in urban areas, in which the green areas with trees are located only between the curb of the street and the fronts of the buildings (not the case of the green areas existing in the spaces provided in the middle of the traffic artery).

Researches were made in projects PN 23 35 01 01, PN 09-14.04.07 and PN 23 35 06 01, and in a doctoral thesis (Zaharia M.C., 1999), by ***calculation studies*** regarding the ***values of the equivalent noise level, Lext (f)***, from ***traffic sources***, - which were performed for ***6 Study transversal profiles of traffic roads***, considering ***many parameters*** and also ***the influence of green areas***.

Table 1. The values of the Coefficient "c_{zv}"

The type of green area	"n"	Czv - for conifer plantations	Czv - for deciduous plantations		Czv - area with grass or earth, etc.
			summer	winter	
Trees in "n" rows with intertwined crowns, with trees and shrubs planted between stems [n = 1 ...3]	n=1 n=2 n=3	1.4+0.4(n-1) 1.4 1.8 2.2	l.4+0.4(n-l) 1.4 1.8 2.2	(n-1) 1.1 1.2 1.3	-
Trees on "n" rows with crowns, not interlaced [n = 1...3]	n=1 n=2 n=3	l.25+0.25(n-l) 1.25 1.5 1.75	1.25+0.25 (n-1) 1.25 1.5 1.75	1.1+0.1(n-1) 1.1 1.2 1.3	-
Area without trees [n = 0]	n = 0	1	1	1	1

RESULTS AND DISCUSSIONS

The ***Study transversal profiles of traffic roads***, are presented, as follow, in Figures 3 to 8.

The values of *Level of noise in measurement point "A", Lext(f),* originated from several types of vehicles moving on the 6 Study profiles of streets, with multiple lanes of a traffic road, bourded with two fronts of buildings, considering different types of parameters including the ***green areas,*** are presented in Table 2.

Table 2. The values of *Level of noise in measurement point "A", Lext(f),*
originated from several types of vehicles moving on the 6 Study profiles of streets

No.	Name of traffic road	Technical Category of street	K'	D (m)	Number of traffic lanes	Number of traffic direc-tions	Traffic composition (no. of lines/no. of vehicles/direction)						Front of buildings		c_s		L_{ech} (dB(A))		
							passenger cars	tram-woe silence.	trolley-bus	micro-bus	silent buses	quiet heavy traffic (trucks)	with shops	without shops	cubic stone	asphalt	winter, summer c_{zv}= 1	summer c_{zv}=1.25	summer c_{zv}=2.2
1	Street profile - Study 1	I	0	43	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**78.58**	**77.15**	-
															0.85	-	**80.85**	**79.41**	
							500					200			-	0.90	**85.05**	**83.63**	
2	Street profile - Study 2	I	a) 3	43	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**67.24**	**66.15**	-
			b) 5												-	0.90	**66.50**	**65.47**	
															0.85	-	**68.67**	**67.65**	
3	Street profile - Study 3	I	10	43	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**65.85**	**64.08**	**62.42**
															0.85	-	**68.18**	**67.21**	**64.75**
4	Street profile - Study 4	I	0	83	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**75.54**	**74.11**	**70.73**
															0.85	-	**77.65**	**76.20**	**72.79**
							500					200			-	0.90	**81.78**	**80.35**	**76.97**
5	Street profile - Study 5	I	a) 3	83	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**63.90**	-	-
			b) 5												-	0.90	**63.22**	**62.21**	**59.69**
															0.85	-	**65.20**	**64.19**	**61.66**
6	Street profile - Study 6	I	10	83	6	2	250	21/30	11/25	-	21/50	-	-	*	-	0.90	**62.63**	**61.66**	**59.21**
															0.85	-	**64.77**	**63.81**	**61.35**

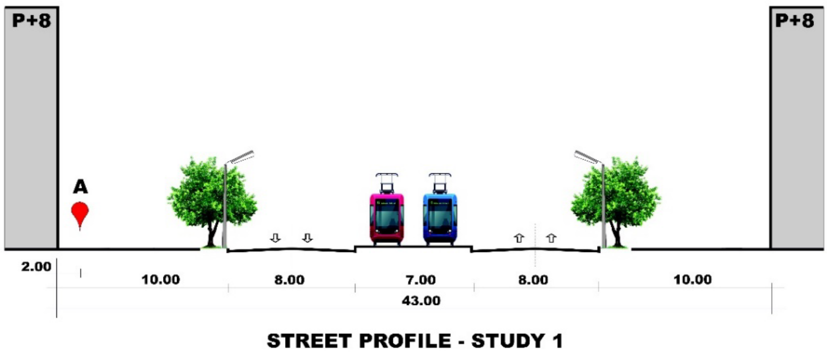

Figure 3. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 1

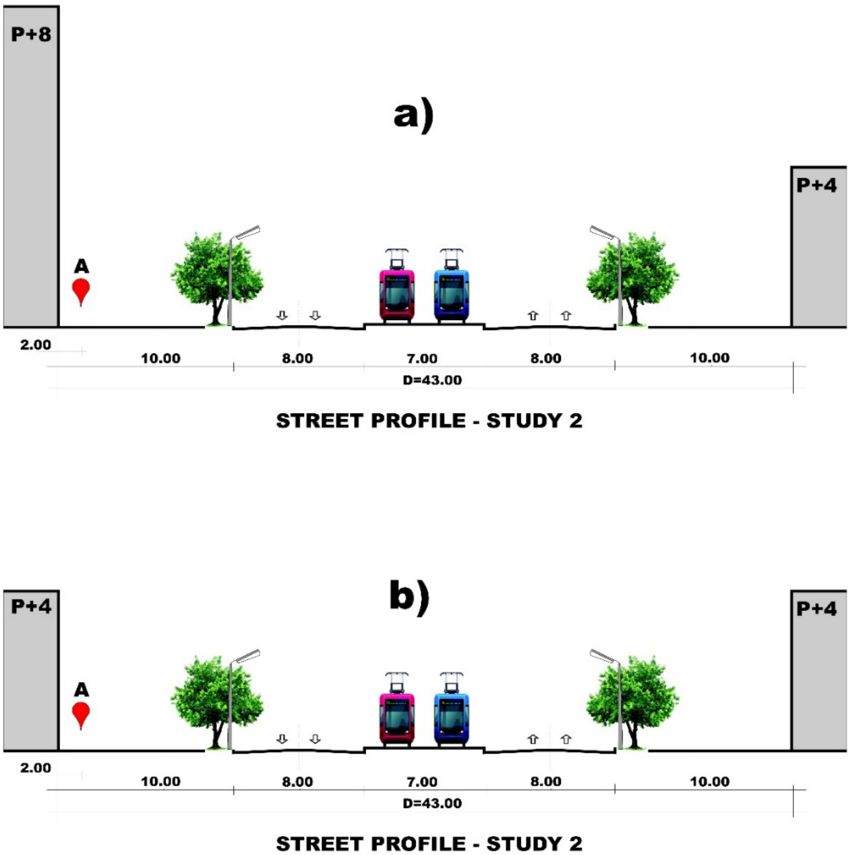

Figure 4. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 2

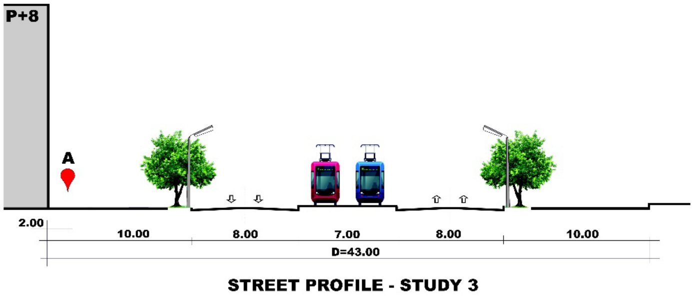

Figure 5. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 3

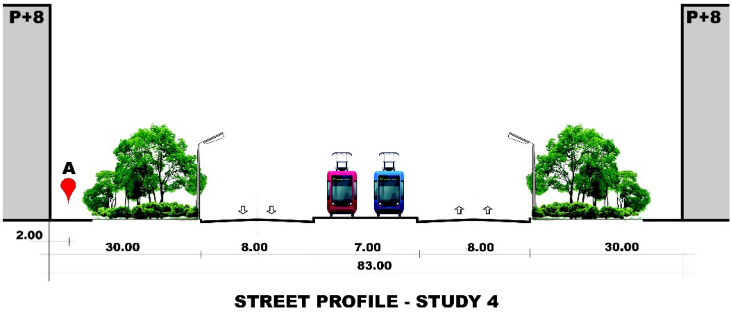

Figure 6. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 4

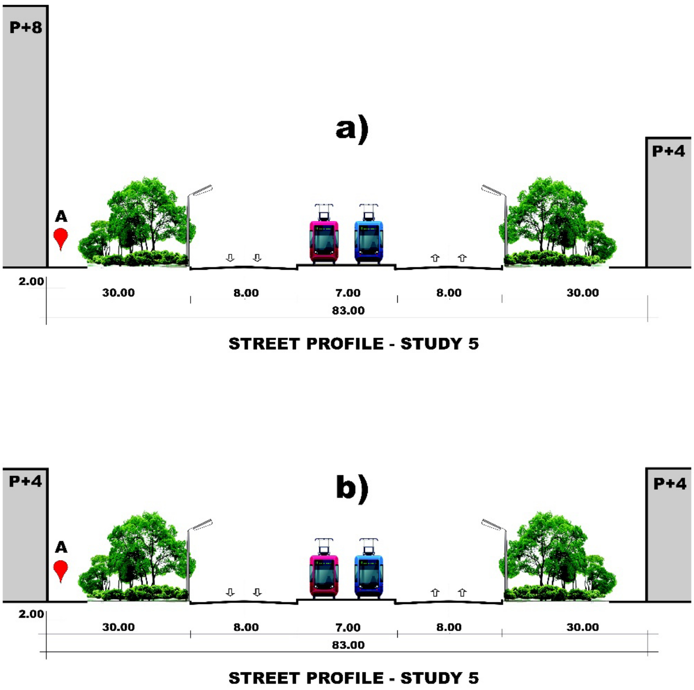

Figure 7. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 5

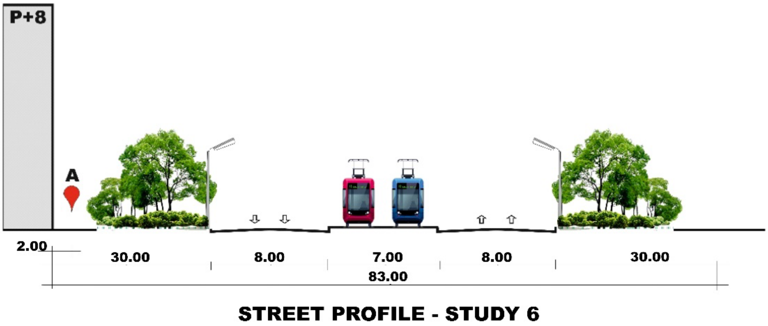

Figure 8. The geometrical elements for determining the A-point exterior noise level, *Lext(f),* on Street profile - Study 6

Analyzing the results obtained from the studies carried out, presented in table 2, for the *6 street profiles-study*, regarding the influence of the variable characteristic parameters of the traffic arteries, including the provision of ***green spaces***, the following main aspects can be highlighted:

a) Increasing the width ("D") of the transverse profile (from 43 m to 83 m) leads to noise reductions of 3 ... 5 dB(A). It should be noted that the effect of increasing the width of the profile is less than decreasing the height regime of the bordering buildings.

b) The variation of the height regime, in the case of streets bordered by two fronts of buildings, can lead to a decrease in the noise level value by up to 10 dB(A) (by moving from delimiting buildings with a height of "P + 8 floors" to buildings with the height "P + 4 floors" or less).

c) The provision of ***green spaces*** leads to a decrease in the noise level by 1...5 dB(A) compared to the case when such spaces are not provided. This difference is evident during the leafing period (summer).

d) The type of road surface also influences the noise level, in the case of asphalted arteries obtaining noise levels 2 ... 3 dB(A) lower than in the case of arteries paved with cubic stone.

e) In the case of arteries bordered only on one side by buildings, with the height "P + 8 floors", the noise level can be 12 ... 15 dB(A) lower than in the case of arteries bordered on both sides by buildings with the height "P + 8 floors".

f) In the case of a street profile of technical category I, having: - distance D = 43 m (between building fronts); - fronts of delimiting buildings, with the height "P + 8 floors"; and - traffic composition: no heavy traffic (trucks); the noise level value is approximately 77 ... 80 dB(A).

g) The influence of heavy traffic in establishing the acoustic regime is decisive, its presence can lead to increases in the noise level of more than 6 dB(A), depending on the width of the street profile and the height regime of the bordering buildings.

CONCLUSIONS

From the studies performed it was shown that for a ***traffic street of technical class 1*** (with ***6 lanes of traffic***), ***bordered*** by ***two fronts of buildings*** of ***maximum 8 floors high***, having a ***complex composition of traffic***, in case of *2 types of* ***distances (43 m*** *and* ***83 m)*** *between the fronts of buildings*, the two cases: without and with ***green area*** made by ***trees, shrubs and grass***, indicates that values of transmission noise may ***decrease between 1 to 5 dB***, depending on ***the winter*** and ***summer seasons***.

ACKNOWLEDGEMENTS

This research work was carried out from the following projects:

- PN 09-14.04.07 "Methods to combat urban noise. Analysis and multi-criteria solution of the acoustics of buildings and living areas in urban and rural areas exposed to noise".
- PN 23 35 01 01: “Integrative concept for the digital analysis of data from the large-scale seismic monitoring of the national territory and built environment, aimed for rapid identification of the destructive potential of

seismic events occurring in Romania and in the adjacent regions”,
- PN 23 35 06 01: “Integrated IT & urban planning system for evaluating the green-blue infrastructure of Romanian municipalities and cities, in order to be implemented in their General Urban Plans. Case study: Râmnicu Vâlcea Municipality”; all financed by the Romanian Government founds.

REFERENCES

C125:2013. Normative regarding acoustics in buildings and urban areas,

C125:2013. Part IV - Protection measures against noise in urban areas.

Bălan, St., Cristescu, V. Cornea, I., (1982), (Coordinators): The Romanian earthquake of March 4, 1977, Ed. Academy, Bucharest, 1982. Chap. VI, pp. 238-239; Head. VI, pp. 347-348, 351.

Hyung Suk Jang, Ho Jun Kim, Jin Yong Jeon, (2015). Scale-model method for measuring noise reduction in residential buildings by vegetation, *Journal Building and Environment*, *86*, 81–88, https://www.sciencedirect.com/science/article/abs/pii/S0360132314004375

Scamoni, F., Scrosati, C., Depalma, M., Barozzi, B., (2022). Experimental evaluations of acoustic properties and long-term analysis of a novel indoor living wall, *Journal of Building Engineering*, *4*(1), 98–16. 103890, https://www.sciencedirect.com/science/article/abs/pii/S2352710221017484

Van Renterghem, T., Botteldooren, D., (2009). Reducing the acoustical façade load from road traffic with green roofs, *Journal Building and Environment*, 4(5), 1081–1087 https://www.sciencedirect.com/science/article/abs/pii/S0360132308001923

Zaharia, M.C., (1999). Contributions regarding the evaluation and combating of urban noise, Doctoral Thesis, - Faculty of Faculty of Civil Construction and Architecture, Ghe. Asachi Technical University - Iasi, Romania.

Zaharia, M.C., Delia, M.F. (2014). Chapter 21. Romania, in: Rasmussen B., Machimbarrena M. (Editori), COST Action TU0901 - Building acoustics throughout Europe Volume 2: Housing and construction types country by country, COST Office and authors, (2014), COST Action - Publisher: DiScript Preimpresion, S.L., pp. 570, e-ISBN: 978-84-697-0159-1, 352-372, www.costtu0901.eu/tu0901-e-books

Zaharia, M.C. (2020). The Influence of the Coefficient of Acoustic Absorption of the Facades of the Buildings from the Street Profiles on the Noise Level from the Urban Road Traffic, in Conference Paper Proceedings Series of the *10th Annual International Conference on Civil Engineering*, Athens, Greece, https://www.atiner.gr/presentations/CIV2020-0197.pdf, ISSN: 2529-167X.