

Identifying ways to reduce urban noise pollution by road noise prediction

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Abstract. In order to investigate the possibilities of reducing the noise pollution in the central area of Pitesti municipality, acting simultaneously in both possible ways – both by reorganizing the road traffic and by applying noise protection measures – the results of road traffic measurements are to be processed, the main parameters of road traffic used as input data being the traffic structure (the weight of heavy vehicles in traffic flows), the hourly traffic volume and the average speed of traffic. An application was made for Building B of the University of Pitesti, using two different calculation programs for modeling road noise, both of them being based on the British CoRTN model. Taking into account the already existing proposals for the reorganization of road traffic in Pitesti (which represent, at the same time, active measures for the reduction of noise pollution) - that will also have effects on the road traffic in the central area under analysis, as well as the possibility to carry out urban planning for the attenuation of road noise propagation (passive measures to reduce noise pollution), a series of successive scenarios are under analysis. Thus, the first scenario is to reorganize traffic by eliminating heavy traffic in the central area, the second scenario involves the commissioning of the Prundu passage, when the flow of light vehicles will also be reduced, and the third scenario envisages the use of silent ground cover. Continuing the explorations, these active noise reduction measures are followed by scenarios providing for passive protection measures - the use of sound barriers. It is noted that the simultaneous application of these measures, in the most complex scenario, leads to a significant reduction of the noise level, which leads to the conclusion that only by simultaneously applying the determining factors for road noise can the noise level be reached within the recommended limits.

1. Objectives of the paper

The measures for the reorganization of the road traffic in the central area of Pitesti are mainly based on two objectives:

- improving road traffic;
- reducing the pollution caused by motor vehicles, with its two components: chemical pollution and noise pollution.

The reduction of the chemical pollution caused by motor vehicles at the level of Pitesti municipality was the subject of the paper [5], and the problem of reducing the noise pollution by reorganizing the circulation in the central area of Pitesti was dealt with in the paper [4].

The present paper aims at exploring the possibilities of reducing noise pollution in the central area of Pitesti municipality acting simultaneously in both possible ways: both by reorganizing the road traffic and by applying noise protection measures.



For such research, the level of road noise can be estimated only by sufficiently complex noise prediction models that take into account as many factors as possible - traffic characteristics, characteristics of the road surface and of the space between the road and the receiver.

2. Road noise estimation by prediction models function of the traffic

To determine by mathematical modeling what is the noise level resulting from the traffic identified on the road network in the vicinity of the buildings of the University of Pitesti, the results of the road traffic measurements carried out throughout this area [4] were used, the main road traffic parameters obtained being the nature of the traffic (fluent or pulsating), the traffic structure (the weight of heavy vehicles in traffic flows), the hourly traffic volume and the average traffic speed.

In order to carry out the modeling of road noise in the proximity of the road artery in front of Building T of the Faculty of Mechanics and Technology (Gh. Sincai Street), a thorough bibliographic research was carried out, finally accessing on the Internet two programs for calculating road noise – a calculation program of the New Zealand Transport Agency [12], which uses the British CoRTN model and a calculation program using the Dutch road noise assessment model [13], according to the latest Dutch standard in the field, developed in 2002.

Both programs are based on the British CoRTN road noise prediction model, which is suitable for predicting noise along road arteries placed quite far from road junctions.

Thus, the British Calculation of Road Traffic Noise (CoRTN) road model was developed by the Transport and Road Research Laboratory and the Department of Transportation of the United Kingdom of Great Britain in 1975 and was modified in 1988 [7].

The parameters used in this model are: traffic flow size and composition, average speed, road gradient and runway type. The underlying assumptions are moderate wind speed and dry road surface.

The base noise level, corresponding to a distance of 10 m, is determined by the equation:

$$L_{10} = 42.2 + 10\text{Log}(q) \quad (1)$$

where q is the hourly traffic flow and the assumed assumptions are: the basic speed is $v = 75 \text{ km/h}$, the percentage of heavy vehicles is $P = 0\%$, the gradient of the road is $G = 0\%$, the source line is 3.5 m from the edge of the road and the road is singular, with a width of at least 5.0 m.

At a distance D the L_D noise level will have a value to be obtained by adjusting the base noise level:

$$L_D = L_{10} + A_{HV} + A_D + A_G + A_{GC} + A_a + A_B \quad (2)$$

with the adjustments:

- A_{HV} - adjustment function of the speed and the proportion of heavy vehicles:

$$A_{HV} = 33\text{Log}\left(V + 40 + \frac{500}{V}\right) + 10\text{Log}\left(1 + \frac{5P}{V}\right) - 68,8 \quad (3)$$

where V is the traffic speed and depends on the road type and P is the percentage of heavy vehicles in the traffic structure ($P = 100 \cdot q_{HV}/q$, where q_{HV} is the hourly volume of heavy vehicles).

- A_D = adjustment function of distance:

$$A_D = -10\text{Log}(D^*/13.5) \quad (4)$$

where D is the distance from the actual noise source to the receiver (the direction may be oblique) in meters.

- A_G = adjustment function of gradient or tilt of the road:

$$A_G = \left[0,73 + \left(2,3 - \frac{1,15P}{100} \right) \frac{P}{100} \right] G, \quad (5)$$

where G is the gradient of the road, expressed as a percentage. It is to be noticed that the percentage of heavy vehicles P intervenes in the calculation of this adjustment.

- A_{GC} = adjustment function of the ground cover, calculated differently according to the speed value (for $v > 75$ km/h, the depth of the ground cover intervenes in the calculation formula, it being different for concrete and bitumen, for $v < 75$ km/h the following values are adopted: $A_{GC} = -1$ dBA for impermeable surfaces of bitumen and $A_{GC} = -3.5$ dBA for permeable road surfaces);
- A_a = adjustment for viewing angle θ (the angle between the vehicle's direction of travel and the direction in which the receiver is located):

$$A_a = 10 \log\left(\frac{\theta}{180}\right) \quad (6)$$

- A_B = adjustment for shielding made by thin barriers, calculated according to wave propagation mode (directly, through reflection, by diffraction) and to the characteristics and arrangement of the obstacles.

It can be noticed that these adjustments can be grouped in 3 categories, depending on traffic characteristics (A_{HV}), runway characteristics (A_G and A_{GC}), and characteristics of the propagation environment (A_D , A_a and A_B).

Thus, an application was carried out for Building T of the University of Pitesti, in which the lecture and laboratory halls of the Faculty of Mechanics and Technology are located, for the façade from Gh. Sincai Street (see figure 1).

2.1. Evaluating the noise level with the New Zealand Transport Agency (NZTA) software

This calculation program can be used in situations where there is no complex topography of the terrain, i.e. when there is no need to discretize the road artery in several segments as noise source lines, for which to calculate separately the level of noise emitted and then cumulate separately.

Instead, there are several categories, quite current, for road surfaces (including the silent ones). Also, the minimum admissible speed as entry data is 50 km/h, due to the fact that it is designed for road sections in the vicinity of which there are no road intersections.

This type of scenario is very appropriate in the varied situations when the terrain does not have a complex configuration - the road is in alignment (horizontally) and in tiers (vertically), while the buildings in the proximity of the road section have no special architecture.

The data entered in the program define the determining factors for the received road noise:



Figure 1. Urbanistic conditions when modeling road noise in the Building T area.

Road and road traffic characteristics:

- AADT [veh/day] – daily average traffic volume per year (Annual Average Daily Traffic);
- Heavy Vehicles – the percentage of heavy vehicles (with a maximum authorized mass greater than 3.5 tonnes) in the traffic flow, from 0 to 100%;
- Vehicle Speed – average vehicle speed (or traffic flow speed), from 50 km / h up;
- Gradient – the longitudinal slope of the road, in percent, from 0 upwards; for the descending path the value 0 is to be entered.

The data measured or observed in traffic measurements on Gh. Sincai Street [4] in both directions (daily traffic volume: 20,000 vehicles per day, percentage of heavy vehicles: 10%, average speed: 50 km / h; gradient: 0) were introduced.

Geometry of the field:

- Distance to receiver: the distance from the nearest side of the road to the receiver [m].
- Barrier (Yes/No): the existence or non-existence of a barrier (natural or anthropic) between the road and the receiver.
- Height above road: the height of the receiver towards the plane of the road [m].

Sound propagation conditions:

- Average propagation height;
- Percentage of sound absorption by the ground.

Finally, the PDF document containing the input data and the final result was produced in the form of a final report (road-traffic noise calculator) – figure 2.

2.2. Evaluating the level of noise with the Dutch 2002 software

This calculation program is built on the Dutch standard based on the method compliant with the British CoRTN (1988) model, but updated in 2002, a model using traffic data for daytime (7.00 - 22.00) and night time (22.00 - 7.00) in the equations presented above.

In order to study the noise level variance function of the proportion of heavy vehicles, % HV, we used proportions for % HV from 0% to 100% (from 0 to 1500 HV), in the current situation, with an hourly volume in peak traffic times of 1500 veh/h (the equivalence coefficient of heavy duty vehicles

in standard vehicles is automatically used by the software, and corresponds to the one from the *SR 7348/2001* standard: *Equivalence of vehicles for the determination of traffic capacity* and the *AND 584-2002*: $C = 2.5$ norm) and at a night hourly volume of 200 veh/h (figure 3).

Export

Project name:
Nivelul de zgomot rutier la fatada corpului T

Project notes:
Valoarea obtinuta reprezinta o valoare globala medie la nivelul unui an

Generate PDF

Open PDF

Summary

AADT	20000vpd
Heavy vehicles	10%
Speed	50km/h
Gradient	0%
Surface	Stone mastic asphalt
Height above road	5m
Distance to receiver	20m
Barrier	No
Reflective surfaces opposite	0°
View of road segment	180°
Propagation height	1.5m
Ground absorption	<10%

Noise level $L_{Aeq}(24h)$ 65dB

Road Geometry Angle of view Propagation Export

Figure 2. Final NZTA report for the façade of the Building T of the University in the current condition.

Data on road		
Road traffic input data help	Day: 7.00-22.00	Night: 22.00-7.00
Motorcycles per hour	0	0
Cars per hour	900	200
Speed cars	50	60
Number of vans/hr	0	0
Number of heavy trucks/hr	600	0
Speed trucks	50	60
Road surface help	Smooth asphalt	
<input checked="" type="radio"/> kilometers per hour <input type="radio"/> miles per hour		

data on geometry help	
Height of road	0
Horizontal distance in meters from center of road <i>Fill in 0 (zero, not blank!) when you want to calculate the distance for a given noise level</i>	25
Height of house or observer	5
View angle (127 grad= full view)	127
Fraction sound absorbing soil (0=all hard, non absorbing; 1= all absorbing)	0
Percentage reflection from opposite side (0=no surface; 1= all reflective).	0
Distance to reflective surface on opposite side	0
Height of reflecting object (must be at least 5 m)	0
Distance to intersection	0
Calculated Noise Level (Ldn) <i>(Or fill in (>40) if you want to calculate distance; distance must be set to zero)</i>	69
Night LAeq is	56

Figure 3. Final Dutch 2002 report for the façade of Building T of the University in the current situation.

The results obtained by simulation with % HV from 0 to 100%, for an hourly traffic volume of 1500 vh/h, are presented in the following table. The effect of % HV on road noise is observed. The increase in noise as compared to % HV is quasi-linear but substantial, from 65 to 72 dBA.

Table 1. The influence of traffic composition on the noise level in the Dutch 2002 program.

Q = 1500 veh/h; d = 25 m											
%HV	0	10	20	30	40	50	60	70	80	90	100
L_{dn} [dBA]	65	66	67	68	69	69	70	70	71	71	72

It is noted that for the scenario corresponding to the current traffic situation in the area under analysis, with % HV = 10%, the values obtained were virtually equal to those from the two software programs: L_{dn} = 66 dBA with New Zealand Transport Agency software and L_{dn} = 65 dBA with the Dutch 2002 software (the difference is of only 1 dBA), therefore it can be said that these models lead to similar results for the case of the road artery in front of Building T.

But the suitability (plausibility) of these noise prediction models for Building T requires the measurement of the noise level at the façade level at a 5-m height (these being the conditions for the scenario for which road noise modeling has been performed).

This was done with the equipment from the Noise and Vibration Laboratory, located on the first floor on the façade that is the subject of the analyses presented (figure 4), obtaining very close values, the differences being reasonable, below 5%, which allows one to say that the two mathematical models (both based on the British CoRTN model) are realistic for the case of Pitesti municipality.

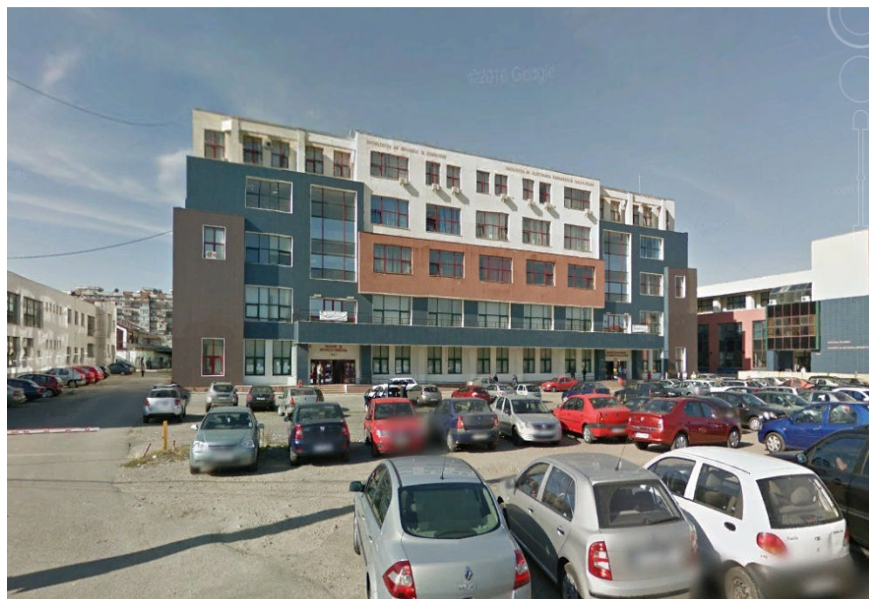


Figure 4. The façade of Building T of the University.

As a result, it can be noticed that for the road arteries where there are no obstacles to the propagation of road noise to buildings, the Dutch 2002 software can be used [13], while for the more complex case, when there are obstacles to noise, the New Zealand Transport Agency software can be used [12], with realistic results.

3. Prediction of road noise in case of reorganization of the traffic in the central area of Pitesti municipality

Taking into account the already existing proposals for the reorganization of road traffic in Pitesti (which represent, at the same time, active measures for the reduction of noise pollution) - that will also have effects on the road traffic in the central area under analysis, as well as the possibility to carry out urban planning for the attenuation of road noise propagation (passive measures to reduce noise pollution), the following scenarios are predicted for the near future for which the prediction of the noise level for the Façade of Building T is achieved.

3.1. Scenario 1 (ban on access for heavy traffic)

As a first step, given the fact that, in traffic peak periods, the capacity of the nearby traffic-light crossing, Maier Sântu, is exceeded by the traffic demand, a measure of reorganizing the road traffic is deviating the heavy traffic on Costache Negri Street, beyond the railroad (figure 5). In this scenario, heavy vehicles will disappear from the traffic so that the noise level can be estimated using the two previously presented software programs.

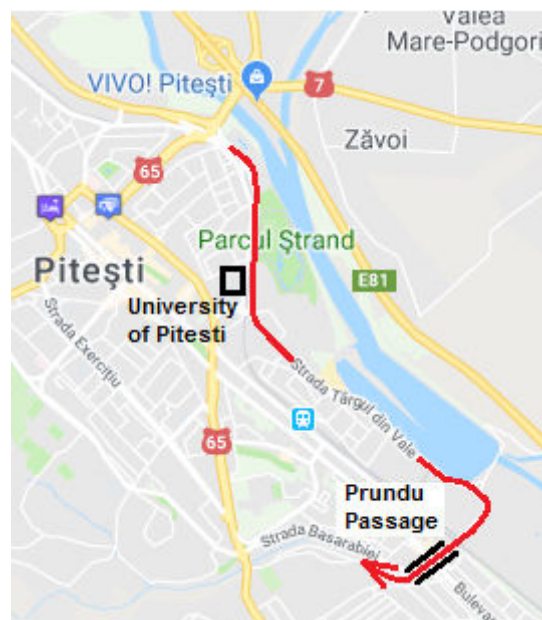


Figure 5. Deviating heavy traffic on C. Negri Str. and the Prundu road passage.

Thus, using the Dutch 2002 software [13], compared to the current situation, when the estimated noise level is 66 dBA, the value of 64 dBA (lower with 2 dBA) is obtained. For the scenario with the elimination of heavy traffic and the New Zealand model [12], the level of the predicted noise also decreased by 2 dBA, from 65 to 63 dBA.

3.2. Scenario 2 (commissioning of Prundu passage)

Under the traffic microsimulation performed with the Vissim software [4], by introducing the future road passage from Prundu (see figure 5), it was found that the flow of light vehicles would also be reduced by about 20%. The following simulations are obtained:

- with the Dutch 2002 software, it is expected to drop by another 1 dBA (from 66 dBA in the current situation to 64 dBA after eliminating heavy traffic, and now, after a 20%-reduction in light traffic, to 63 dBA).

- with the NZTA software, it still drops by another 1 dBA (from 65 dBA in the current situation to 63 dBA after eliminating the heavy traffic and now to 62 dBA).

Thus, compared to the current situation, in the most radical scenario, the noise level would drop by 3 dBA (at a day-night equivalent of 63 or 62 dBA), but far from the limit (50 dBA). It is obvious that other measures, including passive protection measures, are also necessary in addition to traffic reorganization.

3.3. Scenario 3 (silent ground cover)

A first way would be to apply a more silent ground cover. Thus, applying the New Zealand software and the Dutch 2002 software, it can be noticed that a reduction in road traffic noise can also be achieved this way. Thus, by using not the most expensive material (with grain or leather inserts), but only porous asphalt, there is a reduction of another 1 dBA, reaching a noise level of 61 dBA with the New Zealand software or 62 dBA with the Dutch 2002 software, as illustrated in figure 6 and figure 7.

Summary	
AADT	15000vpd
Heavy vehicles	0%
Speed	50km/h
Gradient	0%
Surface	Porous asphalt
Height above road	5m
Distance to receiver	20m
Barrier	No
Reflective surfaces opposite	0°
View of road segment	180°
Propagation height	1.5m
Ground absorption	<10%

Noise level $L_{Aeq}(24h)$ 61dB

Figure 6. Final NZTA report for the façade of Building T in case of traffic reorganization.

Another way that can be applied at the same time is of an administrative nature, to stimulate manufacturers to equip cars with silent tires, which can lead to a reduction in tire noise by even 3 dBA.

4. Prediction of road noise emitted when noise protection measures are applied

Since sound protection barriers can be used and the New Zealand Transport Agency software allows for sound barriers to be considered, it is interesting to note the effect that these barriers would have, because this sound protection is relatively easy to be applied in the case under analysis.

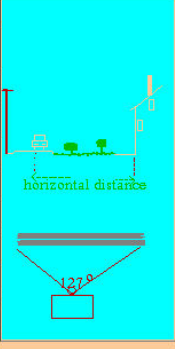
Thus, resuming all the previous 3 scenarios, but adding the condition of placing a noise barrier (which may even be a barrier of vegetation), the following situations arise.

The condition regarding an additional barrier, located 5 m away and 1.5 m high, was applied in the current situation and for the three scenarios already studied:

- current situation: AADT = 20,000 veh/day, of which 10% heavy vehicles (HV);
- scenario 1: traffic without HV;
- scenario 2: traffic without HV and 20% fewer light vehicles;
- scenario 3: traffic without HV, 20% fewer light vehicles and with silent ground cover).

Data on road			
Road traffic input data help		Day: 7.00-22.00	Night: 22.00-7.00
Motorcycles per hour	<input type="text" value="0"/>	<input type="text" value="0"/>	
Cars per hour	<input type="text" value="1150"/>	<input type="text" value="150"/>	
Speed cars	<input type="text" value="50"/>	<input type="text" value="50"/>	<input checked="" type="radio"/> kilometers per hour <input type="radio"/> miles per hour
Number of vans/hr	<input type="text" value="0"/>	<input type="text" value="0"/>	
Number of heavy trucks/hr	<input type="text" value="0"/>	<input type="text" value="0"/>	
Speed trucks	<input type="text" value="50"/>	<input type="text" value="80"/>	
Road surface help	<input type="text" value="Porous asphalt"/>		

data on geometry help	
Height of road	<input type="text" value="0"/>
Horizontal distance in meters from center of road <i>Fill in 0 (zero, not blank!) when you want to calculate the distance for a given noise level</i>	<input type="text" value="25"/>
Height of house or observer	<input type="text" value="5"/>
View angle (127 grad= full view)	<input type="text" value="127"/>
Fraction sound absorbing soil (0=all hard, non absorbing; 1= all absorbing)	<input type="text" value="0"/>
Percentage reflection from opposite side (0=no surface; 1= all reflective).	<input type="text" value="0"/>
Distance to reflective surface on opposite side	<input type="text" value="0"/>
Height of reflecting object (must be at least 5 m)	<input type="text" value="0"/>
Distance to intersection	<input type="text" value="0"/>
Calculated Noise Level (L_{dn}) <i>(Or fill in (>40) if you want to calculate distance; distance must be set to zero)</i>	<input type="text" value="62"/>
Night LAeq is	<input type="text" value="51"/>



[Click Here to Reset](#) [Compute](#)

Figure 7. Final Dutch 2002 report for the façade of Building T in case of traffic reorganization.

The results from table 2 were obtained.

Table 2. Level of noise predicted in various scenarios.

Scenario	L _{Aeq(24h)} [dBA]		
	New Zealand Software		Dutch software (only without barrier) L _{dn} / L _n
	Without barrier	L _{dn} With barrier, d = 5m, h = 1,5m	
Current situation (AADT = 20.000 veh; 10%HV)	65	63	66 / 56
Scenario 1: without HV	63	61	64 / 56
Scenario 2: without HV and 20% fewer light vehicles	62	60	63 / 54
Scenario 3: without HV and 20% fewer light vehicles and with silent ground cover	61	58	62 / 51

For the most complex scenario leading to the minimum noise level (scenario 3, with a sound barrier), the result obtained with the New Zealand software is illustrated in figure 8.

Summary	
AADT	15000vpd
Heavy vehicles	0%
Speed	50km/h
Gradient	0%
Surface	Porous asphalt
Height above road	5m
Distance to receiver	20m
Barrier	Yes
Reflective surfaces opposite	0°
View of road segment	180°
Barrier height	1.5m
Barrier distance from road	5m

Noise level $L_{Aeq,T(20)}$ 58dB

Figure 8. Final NZTA Report for Scenario 3 with sound barrier.

5. Conclusions

For the case that corresponds to the current traffic situation in the area under analysis (Gh. Sincai Street) we obtained practically equal values with the two software programs used - New Zealand Transport Agency, respectively the Dutch 2002 software, so these models lead to similar results for the case of the road artery in front of Building T. But the suitability (plausibility) of these noise prediction models was also confirmed by the measurement of the façade-level noise with the equipment from the Noise and Vibration Laboratory, under the conditions for which the road noise modeling was performed. Therefore, for the road arteries where there are no obstacles to the propagation of road noise to buildings, the Dutch 2002 software can be used, while for the more complex case, when there are obstacles to noise, the New Zealand Transport Agency software can be used, with realistic results.

Taking into account the already existing proposals for the reorganization of road traffic in Pitesti (which represent, at the same time, active measures for the reduction of noise pollution) - that will also have effects on the road traffic in the central area under analysis, as well as the possibility to carry out urban planning for the attenuation of road noise propagation (passive measures to reduce noise pollution), a series of successive scenarios are predicted for the near future that have led to certain road traffic values obtained through Vissim microsimulation for which the prediction of the noise level for the façade of Building T of the Faculty of Mechanics and Technology is achieved.

Thus, the first scenario is to reorganize traffic by eliminating heavy traffic in the central area, the second scenario involves the commissioning of the Prundu passage, when the flow of light vehicles will also be reduced, and the third scenario envisages the use of silent ground cover. Continuing the explorations, these active noise reduction measures are followed by scenarios providing for passive protection measures - the use of sound barriers. Thus, in a first stage, a measure of road traffic reorganization is the deviation of the heavy traffic on Costache Negri Str., towards Lanariei and Basarabiei Streets. In this first scenario, heavy vehicles will disappear from traffic, so based on new road traffic data, the noise level was estimated using the two dedicated software programs.

The same was done for the following two scenarios:

- scenario 2 (commissioning the Prundu passage), when in the traffic microsimulation by means of the Vissim software, by introducing this road passage (overpass road artery) it was found that the flow of light vehicles on Gheorghe Sincai street will be reduced by approx. 20%;
- scenario 3 (use of silent road clothing), taking into account porous asphalt as ground cover.

It is also revealed that another method that can be applied is of an administrative nature, to stimulate manufacturers to equip cars with silent tires.

It is noted that by going successively through these three scenarios, the noise reduction will be only 4dBA, only in the last scenario going below the threshold of 60 dBA.

It is concluded that, along with the reorganization of road traffic, other measures, including passive protection measures, are also needed.

Thus, resuming all three previous scenarios, but adding the condition of a noise barrier (which may be a vegetation barrier), reductions of 2-3 dBA have been obtained for each scenario, the noise levels going just below 60 dBA, within the range of recommended limits. It is noted, however, that these passive protection measures are valid for the surface of the buildings, but for the pedestrians on the sidewalk adjacent to the road artery these passive protection measures cannot be applied, so for these pedestrians, only active measures concerning road traffic can be determined by organizing road traffic (and possibly equipping the vehicles with silent tires).

The final conclusion is that the noise level drops under the threshold value when traffic-related measures are taken so that all determining factors are favourable (heavy traffic deviation, fluent traffic, stable and moderate engine regimes, low speeds, reduced values of traffic density, silent asphalt, silent tires).

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