Green Areas in the City as an Element of Noise Protection

Alicja Kowalska-Koczvara, Filip Pachla, Tadeusz Tatara, Krzysztof Nering
Cracow University of Technology, Warszawska 24 St., 31-155 Cracow, Poland
akowalska@pk.edu.pl

Abstract. From the dawn of history, humanity created communication routes in order to move efficiently. Trees were planted along the roads connecting towns and villages so that travellers could rest in their shade. The line of trees also played an informative, strategic and sometimes aesthetic role. Currently, a line of tall vegetation along the street provides shade and relief in cities during hot weather. It is also worth emphasizing that greenery reduces stress factors in large cities. One of the stressors in cities is noise. In an urbanized environment, noise is perceived as unpleasant and bothersome. Appropriate planting of greenery in the city can reduce this phenomenon. The article not only analyses the possibilities of reducing noise through appropriate planting of greenery, but also provides guidelines for the correct design of greenery along streets and at crossroads. It is worth emphasizing here that the correct design of greenery in the vicinity of communication arteries is not only a matter of ethics or landscape legibility, but also a matter of safe use of infrastructure. The article also deals with the issue of legal acts relating to the design of urban greenery. The former and current legal acts contain provisions related to the classification of green areas, their protection and shaping. These regulations apply to various fields (construction, spatial planning, environmental protection) and therefore there are discrepancies in the legal interpretation of this term. All these doubts will be clarified.

1. Introduction
The 21st century can already be called the age of sustainable development. Public awareness of environmental protection and what will remain after us has increased. We can find sustainable development in many aspects of life, but also in many areas of science and economy[1-2]. Even in a field as resistant to innovation as construction, this aspect is visible [3-5]. The twentieth century is a rush to modernity. We made many mistakes, for example in shaping urban spaces [6-7]. Learning from our mistakes, we can see the role of, for example, green areas in shaping public spaces [8].

Greenery plays a special role in communication routes. These areas can act as small oases of greenery, giving the inhabitants of large cities the possibility of contact with nature. Their primary role, however, is to designate communication routes, increase the visibility and readability of roads, ensure safety of passage, etc. The most important functions of the greenery along the roads are listed below:
1. Isolation function - elimination of negative impacts of traffic on the nearby road environment,
2. Technical function - improvement of driving comfort through barriers constituting anti-glare, sun protection, anti-wind and snow protection,
3. Landscape function - green as an element of the natural environment,
4. Natural function - influence on the condition and quality of the urban environment,
5. Social function - improving the aesthetic values of the environment, masking the unsightly elements of the environment.
Correctly selected greenery performs the above-mentioned functions well, however, poorly selected, sick, badly planted and weeding spit plants do not fulfill their role, and may even be a threat to human health and property.

This article focuses on the role of greenery in the vicinity of communication routes, which will be a barrier to protect against noise. In an urbanized environment, noise is perceived as unpleasant and bothersome. The World Health Organization (WHO) has published a series of reports discussing how and to what extent environmental noise affects society, both physically and mentally [9-10]. Appropriate planting of greenery in the city can reduce this phenomenon. Road traffic noise pollution is one of the main urban environmental challenges nowadays. However, architects and urbanists take decisions on urban regulations that define the shape of streets and buildings without taking this aspect into account. Furthermore, there is little information about the influence of urban geometry on traffic noise exposure in streets. Unpleasant, annoying and bothersome noise in the urban environment accompanies human life from the moment of intensive development of the automotive industry and industry. While the noise emitted to the environment by industrial plants has a more point-like impact (on smaller areas), traffic noise (road, rail, etc.) is characterized by a very large range of impact. There are dense road networks in cities, each of which is a linear source of noise characterized by the level of acoustic power per 1 meter of road in the range of $75 \div 95 \text{ dBA} / \text{m}$, depending on the intensity and structure of traffic. Therefore, there is a need to consider the possibilities of reducing noise in cities and to analyze possible noise abatement solutions in terms of their effectiveness.

The most frequently used noise reduction solutions in agglomerations municipalities include:
- construction of road noise barriers,
- use of low-noise surfaces,
- evacuating traffic from the city, e.g. to ring roads,
- reducing the driving speed of motor vehicles,
- reducing the share of heavy vehicles in the general traffic flow,
- the use of greenery around roads.

The latest method has not been very popular in recent years, but expensive and not very aesthetic noise barriers have been commonly used. In the era of sustainable development, however, it seems appropriate to return to those natural barriers that not only please the eye, provide shelter for animals and birds or reduce the temperature in the city [11-12].

Road noise is a significant environmental and health problem throughout the European Union. According to the latest WHO data [13], about 40% of the EU population (200 million) is exposed to road noise exceeding 55 dBA during the day, including 20% (100 million) - to noise exceeding 65 dBA during the day, while over 30% (150 million) - for noise exceeding 55 dBA during the night.

Research on the acoustic climate conducted in Poland in the 1990s proved that approximately 21% of the area and 33% of the population in Poland were exposed to excessive noise [14]. Based on the results of measurements carried out by the Chief Inspectorate of Environmental Protection in the years 2000-2010 [15], a clear upward trend was found in the risk of road noise, which is related to the increase in the density of the road and street network and the number of motor vehicles.

2. **Acoustic climate assessment indicators**

Among the indicators that allow for the assessment of the acoustic climate, two groups can be distinguished:
- basic indicators, which are a physical description of acoustic phenomena;
- complex indicators which, in addition to the physical nature of the phenomena, also take into account the effects of noise (hazard area, size of threats from the point of view of the response and number of people at risk, etc.).

The basic assessment indicators related to road noise include [16]:
- A sound level \( L_{A} \) (dB) - defined as the A-weighted sound pressure level,
- A-equivalent sound level \( L_{Aeq,T} \) (dB) - this is the value of the ten times decimal logarithm from the ratio of the mean square of the sound pressure, corrected according to the frequency characteristic A, to the square of the reference pressure \( p_0 \), in a given reference time interval \( T \).

The equivalent level is the basic indicator (parameter) of the numerical description of the acoustic climate. The reference time \( T \) in the measurements may in principle be any given period. The most common periods are 15 minutes, 1 hour, day or the periods of the day used in the analyzes of the acoustic climate, i.e. 16 hours from 6.00 to 22.00 \( (L_{Aeq,D}) \) and 8 hours at night from 22.00 to 6.00 \( (L_{Aeq,N}) \),
- sound exposure level A \( (L_{AE} \) or SEL) - definition analogous to the equivalent sound level, with the proviso that the conversion takes place instead of the observation time \( T \) into the conventional reference time \( t_0 = 1 \text{s} \),

The complex indicators of the acoustic climate assessment taking into account the effects of noise impact include:
- LMZHK indicator specifying the percentage of the population of the area (city, province, country) at risk of excessive traffic noise;
- TMZH index defining the ratio of the area of a given area polluted with excessive noise to the total area of this area;
- the M index, sometimes called the "social demand for noise protection measures", takes into account the amount of exceeding the permissible sound level in the studied area and the number of inhabitants exposed to this noise,
- the automotive environmental pressure index \( Z_m \) combines the volume of vehicle traffic with the density of the road infrastructure in a given area, so that its value becomes proportional to the noise pollution.

Acceptable levels of traffic noise in the environment for Poland (Table 1) are specified in the Regulation of the Minister of the Environment of 1 October 2012 [17].

### Table 1. Limits of noise in the environment for roads and railways. [17]

| No. | Type of terrain                                                                 | assessment of the acoustic climate | long-term policy         |
|-----|--------------------------------------------------------------------------------|------------------------------------|--------------------------|
|     |                                                                                  | \( L_{Aeq,D} \) (6.00 – 22.00)    | \( L_{Aeq,N} \) (22.00 – 6.00) | \( L_{DWN} \) all day     | \( L_{N} \) (22.00 – 6.00) |
| 1   | a) Spa protection zone "A"                                                       | 50 (50)                           | 50 (50)                  | 50 (50)                   | 50 (50)                   |
|     | b) Hospital grounds outside the city                                            |                                    |                          |                          |                          |
| 2   | a) Single-family housing areas                                                  | 61 (55)                           | 61 (55)                  | 61 (55)                   | 61 (55)                   |
|     | b) Areas of social welfare homes                                                |                                    |                          |                          |                          |
|     | c) Hospital grounds in cities                                                   |                                    |                          |                          |                          |
a) Areas of multi-family housing and collective housing
b) The area of homestead buildings
c) Recreational and leisure areas
d) Residential and service areas

|   | 65 (60) | 65 (60) | 65 (60) | 65 (60) |
|---|---------|---------|---------|---------|

3.

3. Designing urban greenery nearby routes

Due to the shape of plants, their spread and root development, there are guidelines on how to plant trees along roads. Calculations of minimum areas and minimum soil volumes should consist of 5 stages (Figure 1) following [18]:

1) species selection [specification of species parameters, including crown radius]
2) calculation of the crown projection area [circle formula]
3) calculation of the minimum soil volume [in m$^3$ / using the indicator *] [index value: 0.6 m$^3$ (0.9 m$^3$) per 1 m$^2$ of the wheel surface [contour of the crown projection]
4) determination of the width of the pavement
5) specifying the minimum width of the green belt [width / length]

![Figure 1. Tree crown projection area](image)

Model parameters of the distance between trees with specific parameters of the greenery is listed in Table 2.
Table 2. Model parameters of the distance between trees with specific parameters of the greenery

| The width of the green belt [m] | length of the green belt (distances between trees) [m] | Land preparation for depth 1m | Land preparation for depth 1.2m | Land preparation for depth 1.5m |
|--------------------------------|------------------------------------------------------|------------------------------|------------------------------|------------------------------|
| 1.0                            | 7.0                                                  | x                            | x                            | x                            |
| 1.5                            | 5.0                                                  | x                            | x                            | x                            |
| 2.0                            | 4.0                                                  | 12.0                         | x                            | x                            |
| 2.5                            | 3.0                                                  | 10.0                         | 30.0                         | 30.0                         |
| 3.0                            | x                                                    | 8.0                          | 25.0                         | 25.0                         |
| 3.5                            | x                                                    | 7.0                          | 23.0                         | 23.0                         |
| 4.0                            | x                                                    | 6.0                          | 20.0                         | 20.0                         |

Green belts facilitating orientation towards the road may be located both outside the road and separate the road lanes from each other (Figure 2). Both methods reduce noise in the environment. External planting reduces noise outside the road and internal planting reduces noise between the road lines.

![Figure 2. Examples of green plantings by roads: a) external planting, b) internal planting](image)

It is also very important to choose the right tree species, as they can have different noise reduction properties (Figure 3) given in [19].

![Figure 3. Noise reduction depending on the type of tree](image)
It is important during roadside plantings that visibility is maintained at the curve or intersection. Therefore, in the very zone of the arc arrow, no plantings from the inside are used (Figure 4).

![Figure 4. Scheme of plantings on the curve of the road](image)

An important aspect of designing plantings along roads is also the observance of the minimum distances from existing urban infrastructure. Depending on the medium with which we are dealing, these distances are as follows:
- distance of gas lines: 2m from bushes, 2m from trees,
- distance of lines of sewage and water pipes 1 m from trees and bushes,
- distance of electric cable lines: 1.5 for trees, 0.8 for bushes.

According to the literature data, greenery is considered to be ineffective against noise. Trees in the leaf state reduce the noise level from 0.03 to 0.35 dB per 1 m of obstacle width, and in leafless state from 0.01 to 0.2 dB [20]. Therefore wherever it is impossible to soundproof the road by planting only, it is possible to use green acoustic screens, which are certainly more environmentally and human-friendly than their classic equivalent (see Figure 5).

![Figure 5. Green acoustic screen](image)
4. Conclusions

Road noise is one of the main environmental problems. Due to its very large impact on human life and health, it generates significant social and economic costs, such as falling property prices and lowering employee productivity. The development of the road network and the rapid increase in the number of vehicles resulting from the growing importance of road transport in Poland and in the world mean that the problem of road noise is constantly growing. Additional factors that, especially in Poland, aggravate this problem even more are: the lack of hierarchy of roads and the route of transit roads through densely built-up areas, the lack of acoustic zoning and the proximity of residential buildings to roads, as well as poor technical condition and considerable age of many vehicles. The above-mentioned factors are the result of poor regulations and incorrect spatial planning, which often relate to the problem of noise in a fairly general degree.

The road noise level depends mainly on: road traffic parameters and conditions, vehicle speed, vehicle tire type, road surface characteristics, road geometry and cross-section, and the topography of the surrounding terrain. The above-mentioned factors, due to their different impact and character, make it necessary to apply various protective solutions in the areas of sound emission, propagation and immission. The most common methods of noise protection are traditional noise barriers.

In the era of sustainable development, however, it would be worth departing from these traditional noise barriers for the sake of more natural plantings along the road that have been used for centuries. Although their effectiveness in reducing noise is described as low [20], apart from the noise reduction function, it has a number of advantages such as reducing the temperature around the road, catching harmful substances from exhaust gases, increasing humidity and, of course, psychophysical advantages, including aesthetics.

The article also highlights the design conditions for such natural covers by roads:
- distances between trees depending on their type,
- relationship between tree species and noise reduction potential,
- the principle of designing plantings at curves and crossings,
- minimum planting distances from urban infrastructure.

The article is therefore a guideline on how to design plantings along roads.

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