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Noise Barrier in Intra-City Transportation

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Abstract: Rapid urbanization, migration and population growth induced demands exceed the carrying capacity of the cities and thus the existing urban infrastructure becomes insufficient. Developments in social life in the metropolitan cities, technological progresses and the related increase in the movements caused introduction of noise to the people's lives. Increase in the length and number of the highways for intra-city transportation in addition to changing life styles cause an increase in the densities, which results in noise pollution in the cities and on the main roads. Noise preventing structures are used to prevent/reduce the noise pollution caused by intra-city transportation. Among these structures, noise barriers and plants as live materials play an active role. In this study, noise sources in the intra-city transportation are described and effectiveness of the measures to reduce noise pollution is discussed.

Keywords: Intra-city transportation, Noise, Noise barriers

Kent İçi Ulaşımda Gürültü Perdeleri

Özet: Hızlı kentleşme, göç ve nüfus artışı kentlerin taşıma kapasitesini zorlamakta ve buna bağlı olarak mevcut kentsel altyapı yetersiz kalmaktadır. Metropol kentlerde sosyal hayatta yaşanan gelişmeler, teknolojik ilerleme ve bunlara bağlı olan hareketlilik artışı, gürültünün de kaçınılmaz olarak insan hayatına girmesine sebep olmuştur. Özellikle kent içi ulaşımda otoyolların uzunluğunun ve sayısının artması ve değişen hayat standartları nedeniyle trafikteki gürültü kirliliğini önlemek için kent içinde uygulanan hızlı artışlar ve yoğunlaşmalar, şehir ve anayollarda gürültü kirliliğine neden olmaktadır. Kent içi ulaşımdan kaynaklı gürültü kirliliğini önlemede/azaltmada gürültü önleyici yapı türleri kullanılmaktadır. Bu yapılardan gürültü perdeleri ve canlı materyal olarak bitki örtüsü aktif bir rol oynamaktadır. Bu çalışmada, kent içi ulaşımdan kaynaklı gürültü kaynakları tanımlanmış ve gürültü kirliliğini azaltmaya yönelik önlemlerin etkinliği tartışılmıştır.

Anahtar kelimeler: Kent içi ulaşım, Gürültü, Gürültü perdeleri

Introduction

Increasing vehicle traffic densities due to the increasing population in developed and developing countries provide individual improvement; however, its social and ecological impact on the environment cannot be underestimated. Increasing urban transportation network resulted in noise pollution, which threatens urban health. Noise pollution is the sound sources negatively affecting and destabilizing living things. Intensive noise pollution caused by the merge of industrial and residential areas and formation of dense transportation network due to unplanned urbanization adversely affects the health of urban dwellers.

There are various measures taken to prevent urban transport network induced noise. These measures are investigated and developed under technical, biological, planning, educational and legal headlines. The studies carried within the scope of the technical and biological headlines showed that vegetation and noise barriers reduce and partially prevent the adverse impacts of the noise. Biological barriers and plant sets contribute to the ecological life in the city and reduce the negative impacts of the noise functionally-aesthetically. Wood, metal, stone, concrete, glass, plastic, PVC and tile barriers can be used as an alternative in the areas where plant materials are inadequate to use.

In this study, plantation as a biological barrier material and other types of noise barriers used to reduce the impacts of urban transportation noise is examined.

Definition and Sources of Noise

Noise is a physical phenomenon created by a vibrating source and it moves with the air pressure waves and stimulates the sense of hearing (Yücel 1995). It is divided into two types: physical and physiological. Air pressure created by the sound waves is called sound pressure, frequency in one second is called Hertz (Hz), the distance at which the vibration reaches in unit time is called the speed of sound (Kurra 1982; Çepel 2002). The sound pressure at 1 m distance from the sound source is called as sound power (Yazgan 1979). Decibel (dB) is the unit of the sound pressure measured by sonometer and used particularly to highlight the medium and high frequencies, to which human ear is sensitive (Yücel 1995). Sound power disseminates in cylindrical shape from a linear source, in contrast to a spherical shape from a point source, and decreases 3 dB (A) every time the distance doubles (Ergun and Kulein 1992). Equivalent Noise Level (Leq) is a measurement scale at dB (A) unit giving the average value of continuous sound energy or sound pressure in a given time (Anonymous 1986).

Noise is described in "The Regulation on Noise Control" published on December 11th, 1986, based on the Article 14 of the Environmental Law numbered 2872, as "the irregular sound spectrum, subjectively unwanted sound form".

Noise sources: Noise can be created by a variety of sources. Noise sources in the Regulation on Noise Control are classified as road and air vehicles; industry, road and construction machinery. The most comprehensive classification for noise groups is under two main headings: interior noise and exterior noise (Kurra 1982). Loud talking, household activities, home appliances and mechanical systems are interior noise sources, while industry and various urban noises are exterior sources. Noise level increases or decreases under the influence of some factors (Demirel et al. 1997).

Noise Borne from Commuting

Industry and rapid urbanization, in addition to increase in the variety and number of transportation systems, resulted in noise pollution, which is a major problem for urban life quality and which creates negative impacts on physiology and psychology of the dwellers.

Increase in transport networks, highways and changing living conditions due to the economic and social development, starting from the mid-20th century, created the traffic concept in urban life. In many parts of the world, especially in our country, urban transportation noise is mainly caused by cars and heavy vehicles. These vehicles cause noise in proportion to their power and speed. Small vehicles cause 50, 58 and 64 dB(A) noise with their 32, 64 and 96 km/hour speed respectively; while noise levels of the trucks with 40 and 80 km/hour speed are determined as 76 and 85 dB(A) (Yazgan 1979).

In percentage distribution of the traffic load in an urban settlement in 24-hour period, the traffic load from 8:00 to 10:00 in the morning, from 12:00 to 14:00 and from 16:00 to 18:00 in the afternoon constitutes 44% of the total daily traffic volume. Furthermore, it was revealed in a survey that 50% of the people were highly uncomfortable when the traffic noise level was 65 dB (A), while 90% stated that they had great discomfort when the noise level was 75 dB (A) (Bendtsen 1999). The noise of a moving vehicle is the total of noises from its power unit (engine, intake and exhaust), cooler fan, powertrain, road noise, breaks, suspension structure and the trunk. The importance degree among these sources depends on the vehicle type and working conditions. In small vehicles, at slow speeds with small gear levels, the engine is the decisive source of the noise. At high speeds with greater gear levels, tire noise exceeds the effects of the engine and powertrain and becomes the main noise source. In large trucks with diesel engines, exhaust, engine and cooling fan noises are more prominent and tire noise might have a certain effect. Generally, in all vehicles, except for diesel-engine trucks, tire-road noise is the most important noise source at 100 km/h and above speeds. This value reduces to 60 km/h in contemporary small vehicles (Anonymous 2014).

Contribution of the noise from the trains and other rail systems to urban traffic noise is quite high. Today, despite the technological developments, noise level of rail systems could only be reduced to 80 dBA (25 years ago this level was reaching up to 100 dBA).

Negative Impacts of the Noise

Noise, which increased along with the rapid urbanization, technological development and increasing population, affects the people differently inside and outside of the buildings depending on the changing circumstances and these impacts may cause serious problems.

Physical Impacts: Hearing loss is the most prevalent negative impact of the noise. Hearing loss can be in the form of an acoustic trauma, temporary hearing threshold change and permanent hearing threshold change. In acoustic trauma, noise sensitive receptor cells in the internal ear start to disappear after a certain noise level and the person have tinnitus and cannot hear squawks. This loss has no recovery (Tekalan 1991). In temporary hearing threshold change, the person has a temporary chance and returns to his former condition after the noise is cut. In permanent hearing threshold change, hearing loss cannot be recovered and the person has no chance to get back to the former condition (Karabiber 1991).

Physiological Impacts: Physiological impacts of the noise in the human body appears as diseases such as difficulty in breathing, dilated pupils, eyelid closure, paled skin, elevated blood pressure, arrhythmia, snapbacks, blood sugar disorders, gastrointestinal disorders, decrease in lymph cells, ulcer, hyperthyroid, asthma and coronary insufficiency (Tekalan 1991; Yücel 1995).

Psychological Impacts: Psychological impacts of the noise cause different effects on people. The effect varies based on the character, level, frequency, duration and time on the same person (Kurra 1990). General psychological impacts are manifested as behavioural disorders, rage, boredom (stress) and general unpleasantness.

Impacts on Performance: The noise causes decrease in performance in terms of business productivity, learning and reading. Many tests show that high level noise affects productivity and fewer mistakes are done when the noise reduces. Mistakes are done as a direct result of mental fatigue caused by noise which makes people cranky (Ünver 2008). Negative impacts of the noise on people vary according to the level of the noise (Table 1).

Table 1. Impacts of the noise on people (Yücel 1995)

Degree of noise	**Noise level dB(A)**	**Negative impact type**
1st Degree	20 dB (A) – 30dB (A)	Psychological disturbance
2nd Degree	45 dB (A) – 50 dB (A)	Sleeping disorder in 50% of the participants
3rd Degree	65 dB (A) – 70 dB(A)	Elevated blood pressure, slowing heartbeat, changes in kidney hormones, changes in breathing
4th Degree	90 dB(A) – 120dB(A)	Hearing difficulties and increase in pain
5th Degree	120 dB(A)	Hearing difficulties in s a short time, stroke or death at 120 dB(A) disaster

Noise Barriers and Plants as Living Materials: There are various technical, biological, planning, educational and legal measures to prevent/reduce the noise which has serious negative impacts on urban life quality and human health.

Plants as Living Materials: Vegetation has positive impacts and benefits on human psychology and ecological balance. Although structural precautions are more effective in preventing noise, methods in which living and combination of living-nonliving materials used are preferred (Harris 1986; Walker 1991; Yücel 1995). Leafy trees and shrubs absorb and reflect noise more and their effectiveness increase with increasing plant thickness, height and density (Knudsen 1978). In order to use the plants effectively, they should be spread on a wide area and should have at least 5 m height. According to Alparslan (1987), reduction in noise level depends on leaf size, leaf state, leaf and needle density and branching. According to the writer, effectiveness of the plants in preventing noise is more associated with their structure instead of their width. The plants to be used to prevent noise should have fairly large and hard leaves. The trees with leaves perpendicular to the noise direction and aligned to cover each other, with dense and coniferous leaf structure, with dense branch and leaves structure up covering the trunk, and with high stature should be chosen (Finke 1980). Plant groups based on their noise preventive abilities is given in Table 2.

Table 2. Grouping of trees and shrubs according to their noise reduction capacities in dB(A) (Ürgenç 1990)

Group	Db (A)	Plant species
I	0-2 dB (A)	*Salix elaeagnos, Chamaecyparis glauca, Thujopsis dolabrata, Buxus sempervirens arbor salicif, Picea asperata, Taxus baccata, Picea glauca, Salix alba., Sophora japonica, Cotaneaster multiflorus, Spirea vanhouttei*
II	2-4 dB (A)	*Chamaecyparis nana, Ligustrum vulgare, Caragana arborescens, Prunus mahaleb, Lonicera korolkowii, Lonicera tatarica, Rhodotypos scandens, Crataegus monogyna, Pyracantha coccinea, Rosa multiflora, Sorbaria sorbifolia, Chamaecyparis pisifera*
III	4-6 dB (A)	*Juniperus pfitzeriana, Betula pendula, Alnus incana, Cornus alba, Cornus sanguinea, Pterocarya fraxinifolia, Forsythia intermedia, Sambucus nigra, Lonicera ledebourii, Acer negundo, Populus canadensis Hybride, Corylus avellena, Tilia cordata*
IV	6-8 dB (A)	*Philedelphus pubescens, Carpinus betulus, Syringa vulgaris, Fagus sylvatica, Ilex aquifolium, Ribes divaricatum, Quercus robur, Rhododendron* spp.
V	8-10 dB (A)	*Populus x berolinensis, Viburnum lantana, Viburnum rhytidophyllum, Tilia platyphyllos*
VI	10-12 dB (A)	*Acer pseudoplatanus*

Cook and Hoverbeke (1977) stated that a belt composed of trees and shrubs with 6-16 m width is effective in preventing noise from commuting with medium speed in the city and the highest effectiveness is obtained if the tree-shrub barrier is close to the noise source and far from the protected area. Ürgenç (1990), states that the barrier should be used at twice the distance from the protected area compared to the distance from the source; the barrier should be parallel to the road; should always be at equal distance from the main road and the protected area along the road. Furthermore, when a noise barrier is formed in a 100 m belt, firstly shrubs should be used in the noise direction, and then short trees should follow at certain intervals in a transition zone and broad leaved and coniferous trees should follow the short trees (Çepel 1994). Studies showed that the plant belt should have at least 100 feet (30.5 m) width to reduce traffic noise effectively along the road (Whitcomb and Stowers 1974). When planting is inadequate or inappropriate to use, non-living materials are used as noise barriers to prevent urban transportation noise.

Noise Barriers: A sound-proof barrier is sound-insulating, comparatively thin and compact structure. This structure might be placed closed to the noise source due to the acoustic reasons. Sound-proof barriers can be produced from aluminium, concrete, wood, glass-like transparent plastic and metal (Anonymous 2008). Performance of different barrier types shows differences based on their height and material. In the literature, noise levels at the target points at different distances from barriers, with different heights, are determined. Noise reduction values at the target points (7-16 dBA) depending on the reflection, shape and type of the barrier are measured. The results according to different barrier type are given in Table 3; while the impact ranges of the noise barriers according to the material used are given in Figure 1.

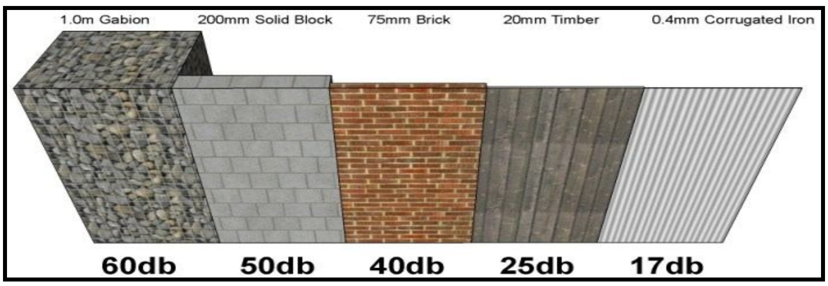

Figure 1. The impact ranges of the noise barriers according to the material used

Table 3. Noise prevention levels of different noise barrier types (OECD 1995).

Barrier type	Barrier height (m)	Target point distance from barriers (m)	Reduction value (dB)	Total reduction (dB)	Calculated value (dB)
Timber	3+1	13	13/10	13/10	16/10
component on set		37	10/10	12/11	15/12
Concrete	2	16	11	11	10
component		40	10/10	14/11	11/8
		70	7/8	12/10	10/8
Timber	2.7	14	11	11	11
component		25	11	12	12
Timber on	3	15	11/9	11/9	13/9
concrete		27	1079	11/9	13/10
Timber	2.7	20	10/8	11/8	14/9
component		33	10/10	14/11	11/10
Timber	2.7	17	12/10	13/10	13/10
component		50	8/8	11/9	8/8
Timber	2+1	18	14/11	15/11	13/10
component on set		50	11/10	14/12	11/9
Earth set	5	25	16/14	17/14	20/18
		43	16/13	18/13	18/16

According to Çalış (2007), the barrier types are classified in five categories:

Wooden Noise Barriers: Wooden noise barriers are generally used on rural roads with heavy traffic load. Their structure generally includes long, narrow strips of wood combined on a concrete surface. There is a layer composed of noise absorbing minerals between them. Many wooden barriers are supported with I-profile metal columns. 4-5 m long wooden barriers are commonly used; they are even used as garden wall and therefore could not have a complete barrier design identity.

Metal Noise Barriers: Metal noise barriers generally absorb noise except for the reflective ones. These barriers have front metal surface with holes and back surface has an aluminium panel without holes. Aluminium is preferred due to its lightness and resistance to corrosion. In the cross-section, mineral wool or other sound-absorbing material is used. On the front surface, generally profile material is used, thus resistance and the gap between the columns are increased.

Concrete Noise Barriers: As in the metal barriers, concrete barriers are classified according to their reflection and absorption features. Reflecting concrete panels and concrete barriers built on site can be used as effective as other barriers if well designed, proportions are well chosen and the planting is used organic and reciprocity. Absorbing concrete noise barriers are divided into two types: wood fibre and granular concrete barrier. There barriers are manufactured in the factory in the desired size and colour and mounted on steel columns on site.

Plastic, PVC and Fiberglass Noise Barriers: These materials are envisaged to be used more in the future as they are recyclable, are resistant to shock and fire, have light refraction and transmittance function, have climate resistant material, their easy installation and use. High number of colours to be used in plastic and flexibility increase the importance of this material as barrier and their noise reduction level is at least 33 dB(A).

Transparent Noise Barriers: these barriers are manufactured from laminated, compressed or reinforced glass, acrylic or polycarbonate plates. The plate thickness is 8-19 mm for glass, 15-20 mm for acrylic or polycarbonate. Although the plate thickness varies from manufacturer to manufacturer, acrylic plates can be cut and shaped on site. However, it is not the case for glass. Due to visual neutrality of these barriers, they are used on visually important traffic zones or in the regions where landscape image should be protected.

Conclusion

The most influential factors in highway noise formation are transportation network, traffic flow and vehicles. The efforts to reduce the vehicle noise are increasing and vehicle noise measurements are being standardized, while limit values are being determined. Various types of noise barriers are used depending on the location and the density of the urban transportation networks. The barriers should be durable and should not include any cracks, holes, slots or open parts. All the construction materials should be resistant to the fire and corrosion, should preserve its form and should be resistant to the impacts of the weather-salty water. Moreover, it should be insensitive to the damages caused by animals and plants. Colour change in coloured elements should be minimal during their lifetime (Çalış 2007). Wooden barriers should be protected from decaying. Precautions should be taken to prevent the harm from evaporation of wood preservatives, transportation of processed products by air or release of toxic solutions. Reflection of light, sun light or reflection of car headlights at night on the glass or transparent barriers disturb the drivers and create traffic safety risk. Therefore, non-reflective glasses should be used as much as possible. Urban use of metal noise barriers can create positive visual effects. Sound absorbing metal barriers can be used with transparent barriers (Çalış 2007). As concrete piles, concrete barriers might be observed as aesthetically week, cold surfaces when used alone. Thus, designs/ practices with contribution of vegetation may exhibit a more aesthetic appearance. Another way might be changing the colour of the concrete block distances to reduce monotonicity. The desired result is obtained when plants as living materials are used to prevent the noise with adequate width and intervals. On the roads planted in the form of green belts, which do not disrupt the traffic in the urban transportation network, the noise can be prevented and traffic safety (channelling effect) can be provided. The species should be chosen among the ones appropriate to the land conditions, pollution-resistant and having aesthetic and functional impacts.

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